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HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., *15 March 1973*

ATTITUDE INSTRUMENT FLYING

TM 1-215, 8 September 1964, is changed as follows:

1. New or changed material is indicated by a star.
2. Remove old pages and insert new pages as indicated below.

Remove old pages—	Insert new pages—
2-33 and 2-34	2-33 and 2-34
5-9 through 5-25	5-9 through 5-25

3. File this change sheet in front of the manual for reference purposes.

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TECHNICAL MANUAL No. 1-215

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., *8 September 1964*

ATTITUDE INSTRUMENT FLYING

* This manual supersedes TM 1-215, 8 December 1958, C 1, 8 September 1960, and C 4, 21 March 1962.

CHAPTER 1

INTRODUCTION

1-1. Purpose

This manual provides guidance in attitude instrument flying for Army aviators and for individuals undergoing flight training.

1-2. Scope

a. This manual covers the various aspects of basic instrument flying. Information contained in the manual covers flight instruments and their systems, the description of in-flight forces and sensations, instrument interpretation and aircraft control techniques, and instrument procedures for performance of fixed wing and rotary wing flight maneuvers.

b. Unless otherwise specified, the material presented herein is applicable without modification to both nuclear and nonnuclear warfare.

c. Users of this manual are encouraged to submit recommended changes or comments to improve it. Comments should be keyed to the specific page, paragraph, and line of the text in which changes are recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded direct to Commandant, United States Army Aviation School, Fort Rucker, Alabama 36362.

1-3. Definition

Attitude instrument flying is the art of controlling performance and attitude of the aircraft by reference to instruments.

CHAPTER 2

FLIGHT INSTRUMENTS AND SYSTEMS

Section I. THE MAGNETIC COMPASS

2-1. General

There are numerous types of heading indicators, most of which are highly complex and which require a power source for operation. The magnetic compass (fig. 2-1), simple in construction and operation, is an exception and is therefore less subject to failure. However, the magnetic compass has many limitations (para. 2-5).

2-2. Basic Magnetism

A *magnet* is a piece of metal that has the property of attracting another metal. When freely suspended, a bar magnet will aline approximately in a north and south direction. The force of attraction is greatest at a point near the end (pole) of the magnet. Lines of force flow out from each pole in all directions, eventually bending around and returning to the other pole. The area through which these lines of force flow is called the field of the magnet. The end of the magnet that seeks north is called the north pole.

2-3. The Earth As a Magnet

The earth is a magnetized body and is comparable to a huge magnet, the ends of which are several hundred miles below the earth's surface.

a. Location of Magnetic Poles. The magnetic poles do not coincide with the earth's geographic poles (fig. 2-2). The approximate location of the north magnetic pole is 71° N and 96° W, and the south magnetic pole is 72° S and 157° E.

b. Dip Angle. The lines of force in the earth's magnetic field are parallel to the earth's surface at the magnetic equator and curve increasingly downward when moving closer to the magnetic poles. In general, when a magnetic needle is placed on one of the lines of force (fig. 2-2) it will assume the same direction and position of the actual line of force. The earth's magnetic field has both horizontal and vertical components (fig. 2-2). Only the

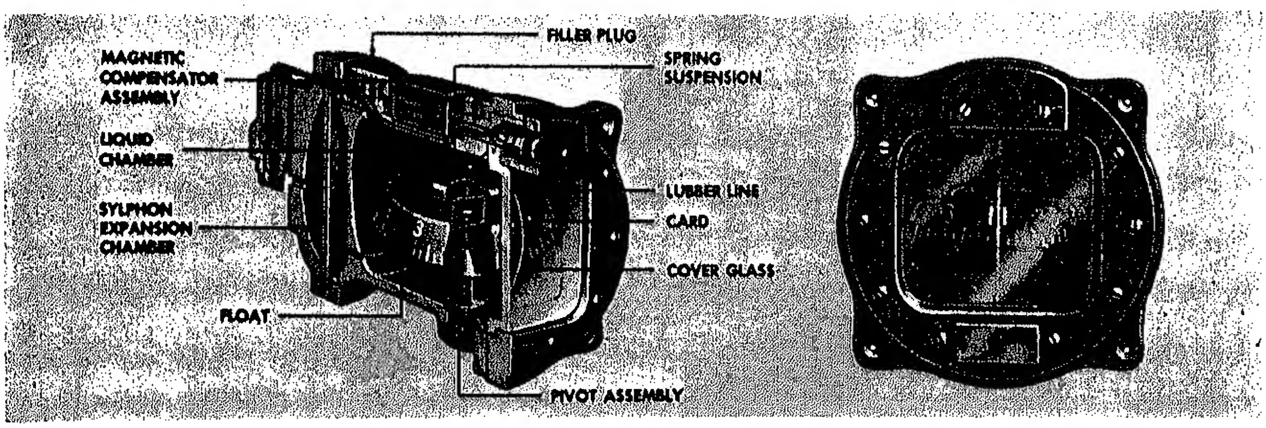


Figure 2-1. The magnetic compass.

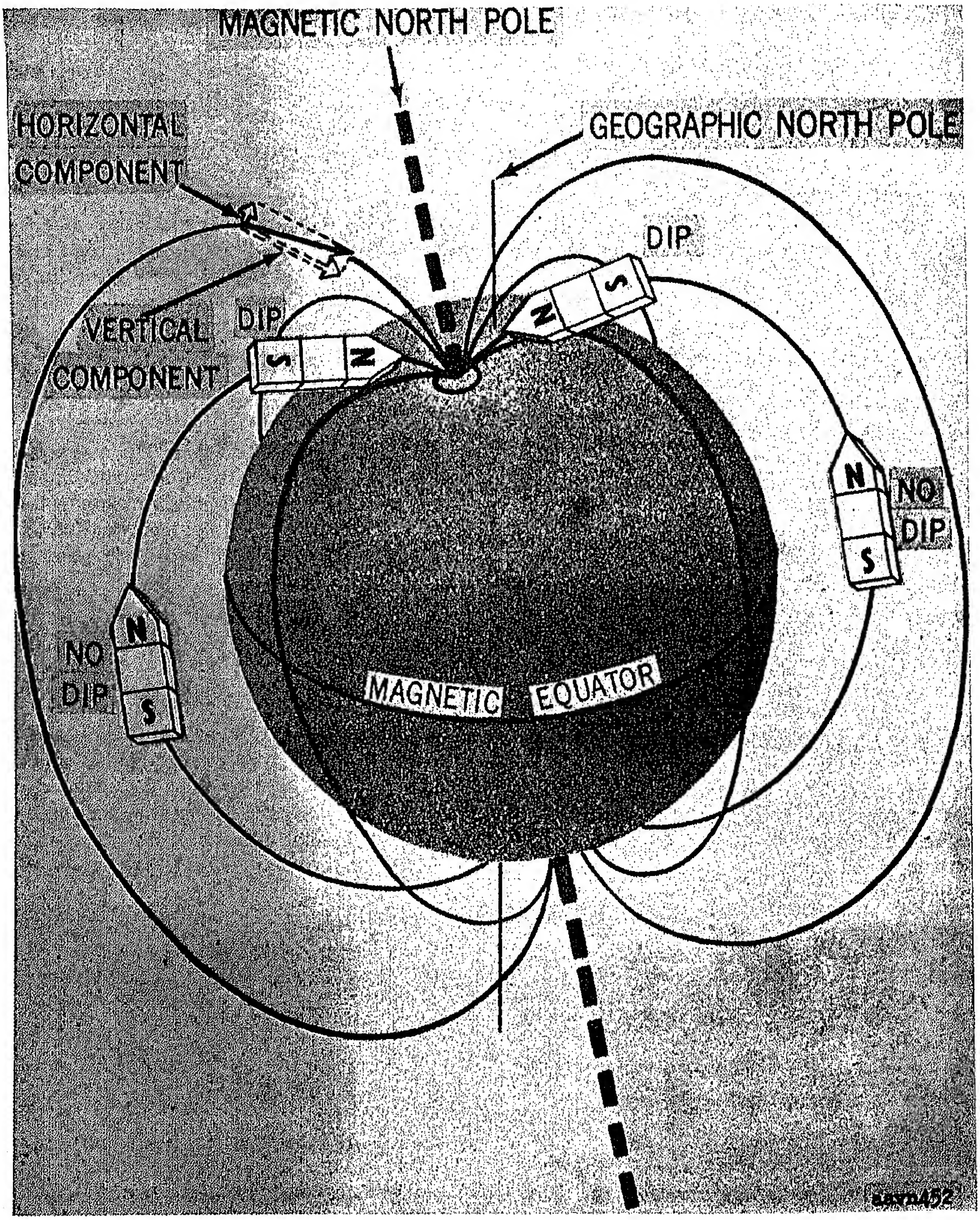


Figure 2-2. The earth's magnetic field.

horizontal component is used for directing finding. If a magnetic needle is placed on a horizontal axis so that its vertical movement is free, it will dip 0° at the magnetic equator and 90° at the magnetic poles. The magnetic compass is reliable until the dip angle exceeds 84° in polar areas.

2–4. Construction

The magnetic compass (fig. 2–1) contains two steel magnetized needles mounted on a float around which the compass card is mounted. The needles are parallel, with their north-seeking ends pointed in the same direction. The compass card has letters for cardinal headings, and every 30° interval is represented by a number, the last zero of which is omitted. Between these numbers the card is graduated each 5°.

a. Dampening Action. The float assembly, which consists of the magnetized needles, compass card, and float, is housed in a bowl filled with acid-free white kerosene. The purpose of the liquid is to dampen out excessive oscillations of the compass card and, by buoyancy, to relieve part of the weight of the float from the bearings. The liquid also provides lubrication and prevents rust within the instrument.

b. Float Mounting. A pedestal rising from the bottom of the bowl supports the float. The float assembly is mounted on jewel bearings on top of the pedestal. At the rear of the compass bowl, a diaphragm allows expansion or contraction of the liquid, which prevents the formation of bubbles or possible bursting of the case.

c. Lubber Line. The glass face of the compass is an integral part of the bowl. Mounted behind it is a lubber (reference) line by which compass indications are read. If the face is broken, the fluid is lost and the compass becomes inoperative.

d. Compensator Assembly. A compass compensating assembly, consisting of several small bar magnets, permits adjustment of the compass by means of two setscrews labeled N–S for north-south and E–W for east-west.

2–5. Compass Errors

a. Variation. In some types of navigation, course computations on aeronautical charts are based upon a relation of the course to the true geographic North Pole. During flight, the magnetic compass points to the magnetic north pole, which is not at the same location as the true North Pole. This angular difference between true and magnetic north is known as *magnetic variation.* Lines of equal magnetic variation are called *isogonic lines* and are shown on aeronautical charts in degrees of variation east or west (fig. 2–3). The line on a chart connecting points of 0° variation is called the *agonic line.* Lines of equal magnetic variation are replotted periodically to compensate for shifting of the poles or changes in local magnetic deposits.

b. Deviation. The magnetic compass is influenced by electrical equipment and metallic objects located near the compass. These magnetic disturbances cause the compass to deviate from its normal reading. The differences between the indications of a compass in a particular aircraft and the indications of an unaffected compass at the same point on the earth's surface is called *deviation.* To reduce this deviation, compensating magnets on the compass are adjusted in the following manner:

(1) On a compass rose, aline the aircraft with magnetic north.
(2) With the N–S screw, adjust the heading until the compass reads 0° or 360°.
(3) Aline the aircraft with magnetic east.
(4) With the E–W screw, adjust the heading until the compass reads 90°.
(5) On headings of south and west, take out one-half the error by adjusting the compensating screws.
(6) Swing the compass through 360°, noting the errors at each 45° mark.
(7) Enter errors on the compass deviation card in the cockpit.

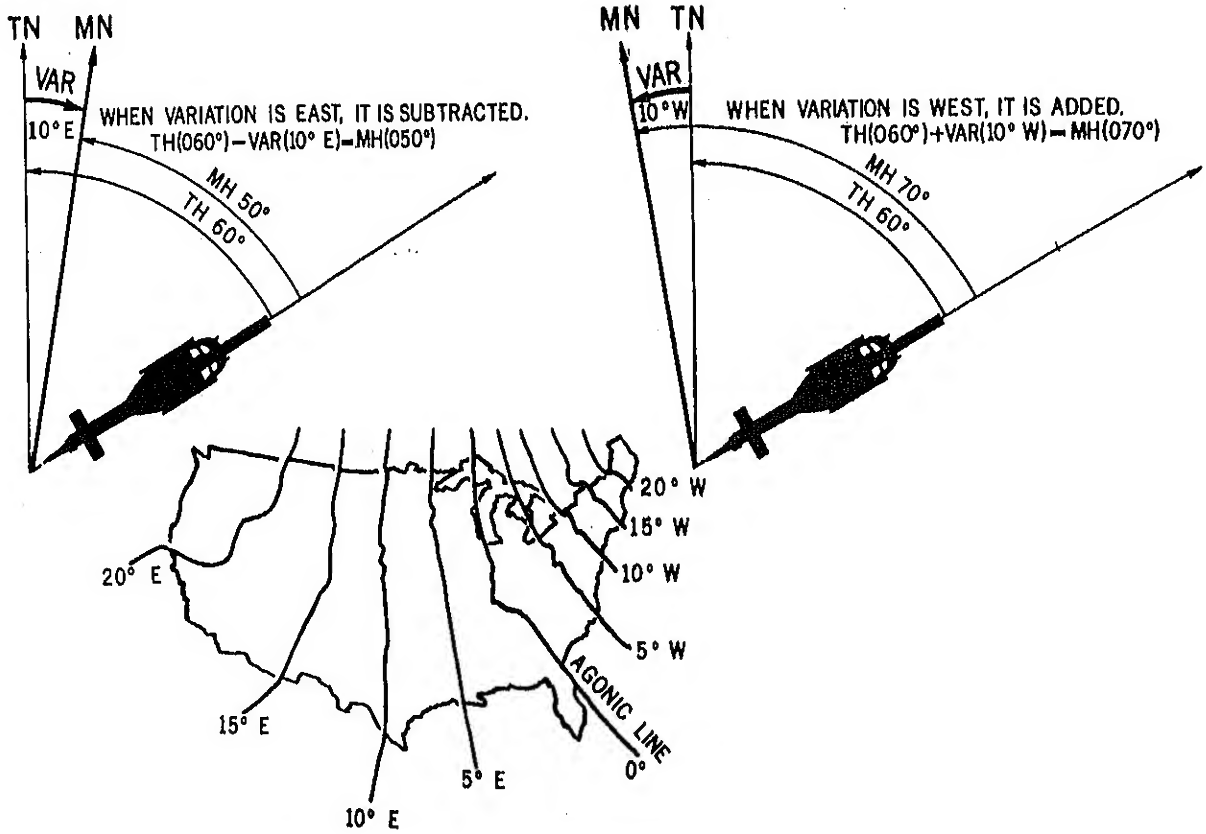


Figure 2-3. Lines of equal magnetic variation in United States.

(8) At periodic intervals, repeat the above steps by swinging the compass and preparing a new deviation card.

c. Magnetic Dip. The tendency of the magnetic compass to point down as well as north in certain latitudes is known as *magnetic dip.* Magnetic dip is responsible for the northerly and southerly turning error and for the acceleration and deceleration error on headings of east and west. At the magnetic equator, the vertical component of the earth's magnetic field is zero and the magnetic compass is not disturbed by this factor. While flying from the magnetic equator to higher latitudes, the effect of the vertical component of the earth's magnetic field becomes pronounced. (Only errors in the northern hemisphere are discussed below; the exact reverse of these errors occurs in the southern hemisphere.)

(1) *Northerly turning error.* Vertical dip tendency is not noticed in straight-and-level unaccelerated flight. The compass card is mounted so that its center of gravity is below the pivot point and the card is well balanced in the fluid. When the aircraft is banked, however, the compass card also banks as a result of the centrifugal force acting upon it. While the compass card is in this banked attitude, the vertical component of the earth's magnetic field causes the north-seeking ends of the compass to dip to the low side of the turn, giving an erroneous turn indication. This error is most apparent on headings of north and south. When making a turn from a heading of north, the compass briefly gives an indication of a turn in the opposite direction and lags behind; when making a turn from a heading of south, it gives an indication of a turn in the

proper direction but at a more rapid rate than is actually being made.

(2) *Acceleration error.* Acceleration error is due to the action of the vertical component of the earth's magnetic field. The pendulous-type mounting of the compass causes the compass card to tilt during changes in acceleration and pitch. This momentary card deflection from the horizontal results in an error which is most apparent on headings of east and west. When accelerating or establishing a descent on either of these headings, the error is an indication of a turn to the north; when decelerating or establishing a climb, the error is an indication of a turn to the south. If the aircraft is on a north or south heading, no acceleration error is apparent while climbing, diving, or changing speed.

(3) *Oscillation error.* Rough air or poor control technique causes erratic swing of the compass card and results in compass oscillation error. The fluid in which the magnetic compass is immersed (para. 2–4*a*) is subject to swirl and this may create noticeable error. Also, the comparatively small size of the compass bowl restricts the use of efficient dampening vanes.

(4) *Errors resulting from the earth's magnetic field.* The earth's magnetic lines of flux must be strong enough to cause a bar magnet (as in a compass) to aline with them. The magnetic compass is mounted so that when an aircraft is in straight-and-level unaccelerated flight, the vertical component of the earth's magnetic field has no effect on the compass indications. In the extreme latitudes (near the North and South Poles), the horizontal component of the earth's magnetic field is very weak and the compass may spin erratically or indicate improper headings.

(5) *Constructional compensation.* All magnetic compasses are constructed to compensate for disturbing magnetic influences within the aircraft. The compensating mechanism is satisfactory when used with a deviation card (*b*(7) above) as long as the deviation on any particular heading is constant. In modern aircraft, however, the deviation is seldom constant, so the use of the deviation card is limited. In the slaved gyro compass system (para. 2–23 through 2–25) the remote compass transmitter is usually located in a wingtip or vertical stabilizer, away from aircraft magnetic disturbances.

Section II. GYROSCOPIC PRINCIPLES

2–6. Gyroscopes

A *gyroscope* (fig. 2–4) is a wheel or rotor mounted to spin rapidly about an axis, and also free to rotate about one or both of two axes perpendicular to each other and to the axis of spin. A spinning gyroscope offers resistance to any force which tends to change the direction of the axis of spin. The rotor (fig. 2–4) has great weight (high density) for its size and is rotated at high speeds; therefore, it offers a very high resistance to any applied force.

2–7. Mountings

There are two general types of gyroscopic mountings—*free* and *semirigid.*

a. Free. A freely (universally) mounted gyroscope has three planes of freedom and is free to rotate in any direction about its center of gravity. The rotor is free to rotate in any plane in relation to the base. The rotor spins so rapidly that its spin axis tends to remain in a fixed direction in space. The freely mounted gyroscope uses the gyroscopic property of *rigidity in space.* The heading indicator

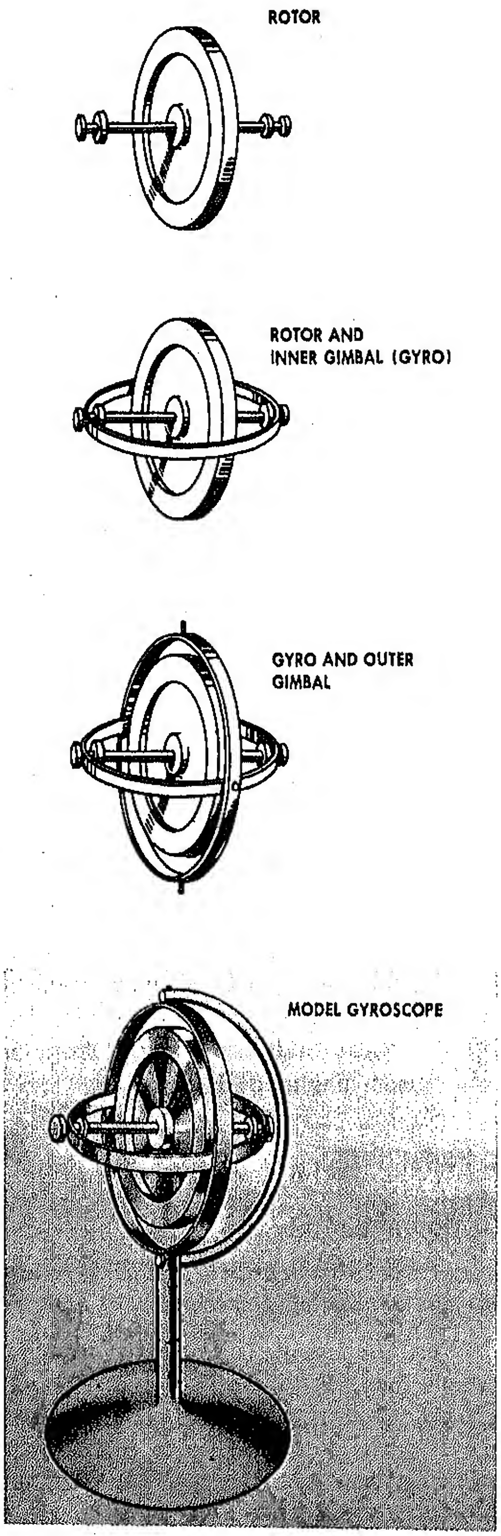


Figure 2-4. Primary elements of a standard gyroscope.

and the attitude indicator are freely mounted instruments.

b. Semirigid. A semirigidly mounted gyroscope is mounted so that one of the planes of freedom is held fixed in relation to the base. It uses the gyroscopic properties of *rigidity in space* and *precession.* The turn-and-slip indicator is a semirigidly mounted instrument.

2-8. Properties of Gyroscopic Action

All practical applications of the gyro are based upon two fundamental properties of gyroscopic action—*rigidity in space* and *precession.*

a. Rigidity in Space. When spinning, the rotor remains in its original plane of rotation regardless of how the base is moved. The rigidity of a spinning body is determined by its weight and angular velocity. To obtain as much rigidity in the rotor as possible, it is designed with great weight for its size and rotates at high speed. To keep the deflective force at a minimum, the rotor shaft is mounted in bearings which are as frictionless as possible.

b. Precession. Precession is the resultant action or deflection of a spinning wheel when a deflective force is applied to its rim. By applying an upward pressure on the gyro spin axis (A, fig. 2-5), a deflective force is applied to the rim of the gyro at point 1. The resultant force is 90° ahead in the direction of rotation to point 2 (B, fig. 2-5). This resultant force causes the gyro to precess (C, fig. 2-5). Precession is classified as *real precession* and *apparent precession.*

(1) *Real precession. Real precession* is a positive deflection caused directly or indirectly by applied force or forces. Real precession is the resultant action characteristic of a spinning wheel when a deflective force is applied to the rim. The resulting force is 90° ahead in the direction of rotation and in the direction of the applied force (fig. 2-5). The rate at which the gyro precesses is in-

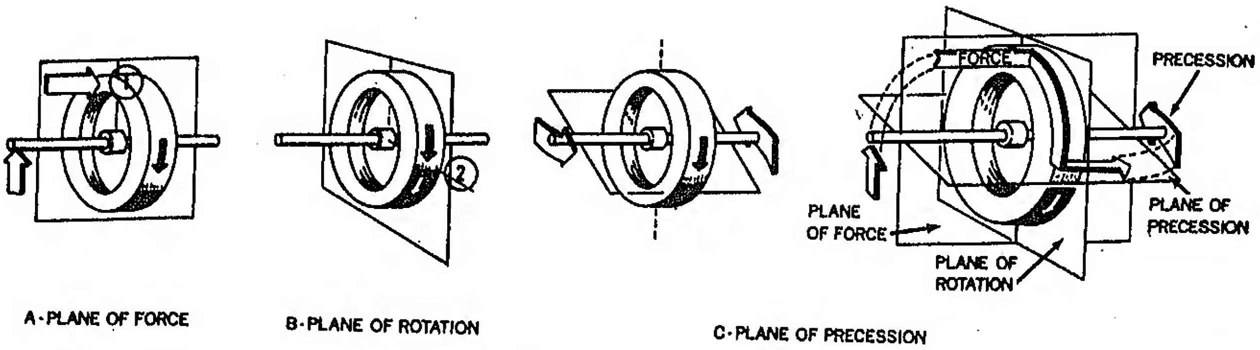


Figure 2-5. Precession.

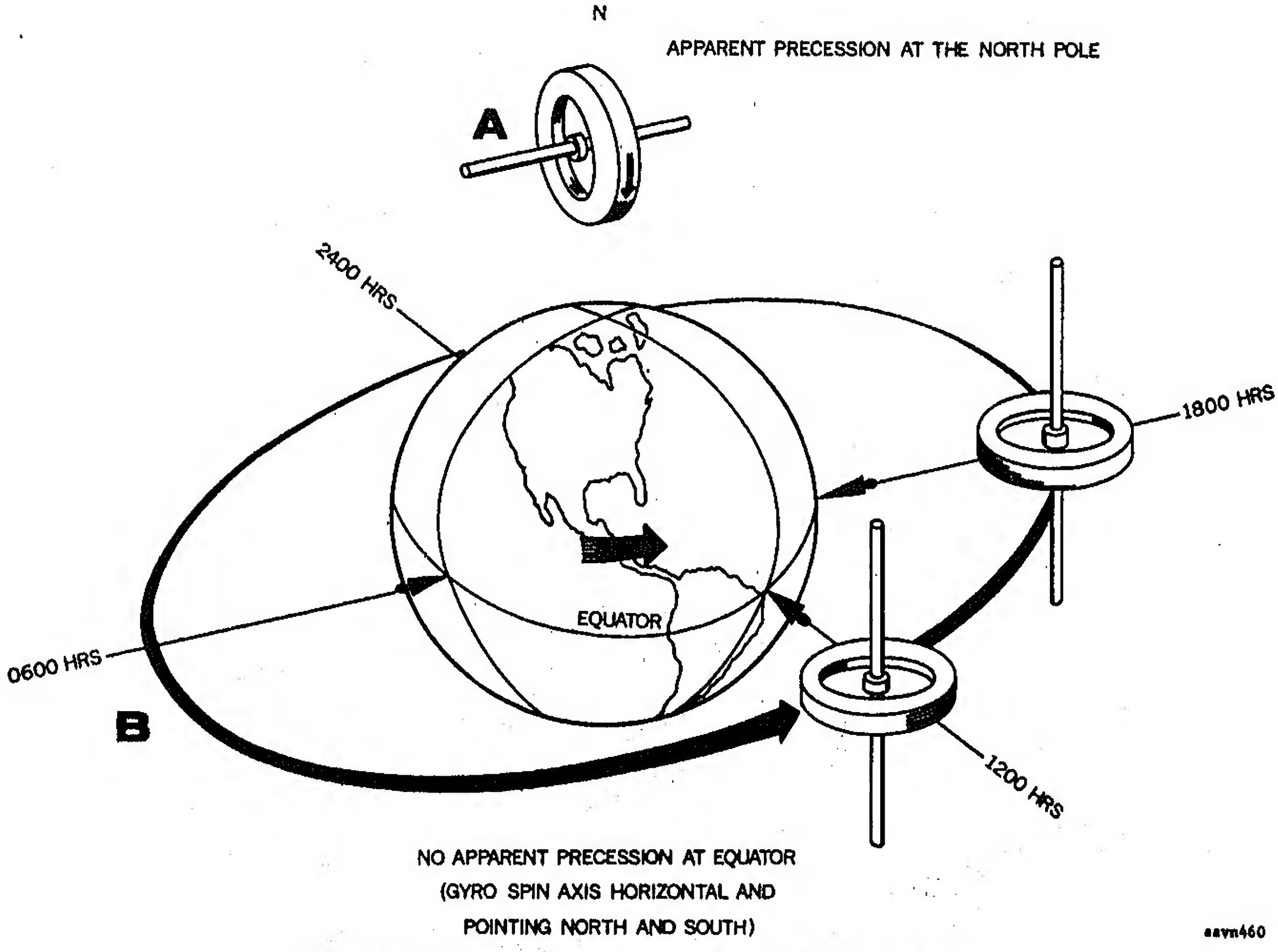


Figure 2-6. Gyro spin axis maintains its direction in space.

versely proportional to the speed of the rotor and proportional to the deflective force. The force of precession is the same as the deflective force applied (minus friction in the gimbal rings, pivots, and bearings). If too great a deflective force is applied for the amount of rigidity in the rotor, it precesses and topples over at the same time. Any gyroscope has some real precession because of imperfect construction (imperfect balance of

the rotor, bearing friction, and friction in the gimbal rings and pivots). Other causes of real precession are centrifugal force, gravity force, and acceleration and deceleration.

(2) *Apparent precession.* A freely mounted gyroscope (para. 2-7*a*) maintains its axis fixed in relation to space, and not in relation to the surface of the earth. A, figure 2-6 shows a free gyro at the North Pole. As the earth rotates, carrying the gyro mount around with it, the gyro spin axis maintains its direction in space. With respect to the earth, the spin axis does change direction; this change in direction is called *apparent precession.* As a result of the earth's rotation, the rate of direction change caused by apparent precession is 15° per hour at the poles.

(*a*) The free gyro shown at the equator (B, fig. 2-6) has its spin axis horizontal, and points north and south. As the earth rotates, carrying the gyro around with it, the spin axis maintains its direction in space and continues to point to true north. There is no apparent precession as rotation of the earth carries the gyro to the successive positions indicated.

(*b*) At points between the Equator and the pole, the rate of apparent precession is a function of latitude. Figure 2-7 shows a free gyro at 30° north latitude. The spin axis is horizontal to the surface of the earth (A, fig. 2-7) and points along the meridian toward true north. Three hours later, rotation of the

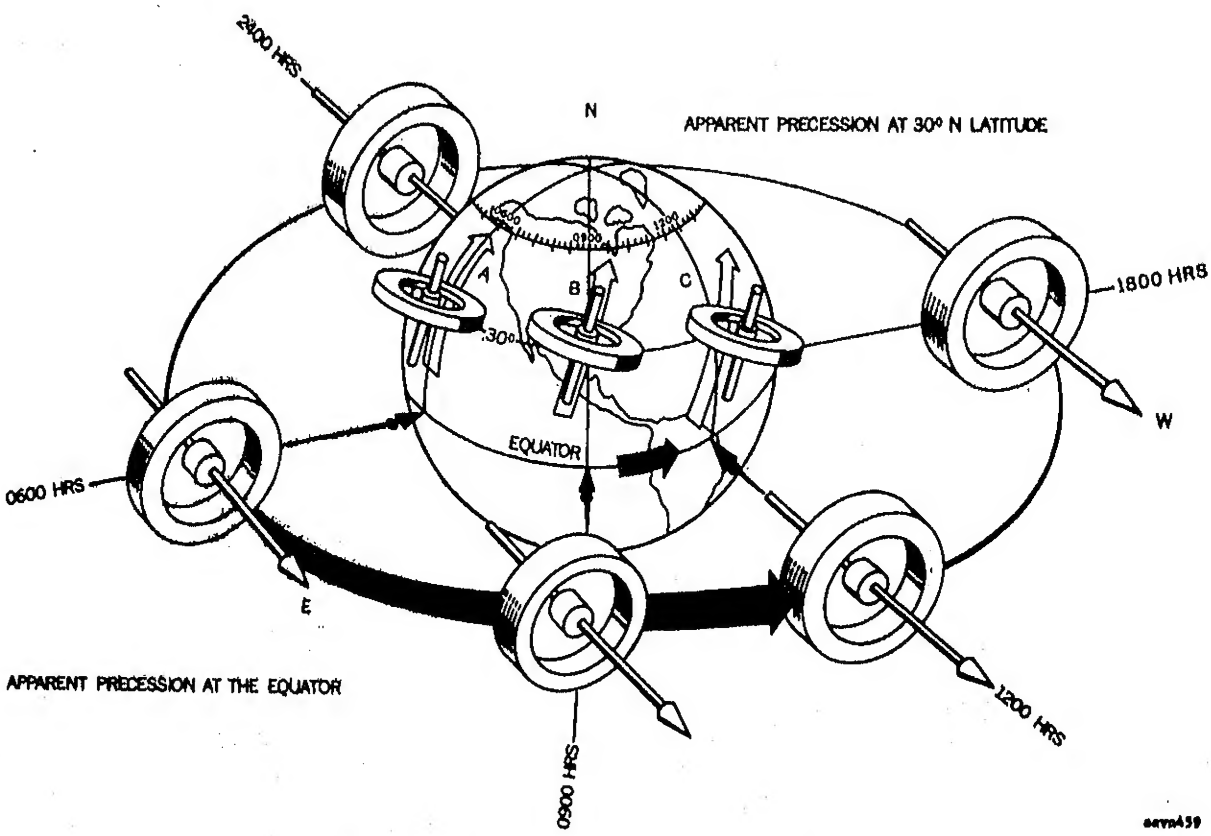


Figure 2-7. Apparent precession of a free gyro.

earth has carried the gyro to position B, figure 2-7. At B, the spin axis still has its original direction in space. With reference to true north, the spin axis has turned in a clockwise direction about an axis that is vertical to the surface of the earth. At position C, figure 2-7, the spin axis has turned still further from true north due to apparent precession.

(*c*) Apparent precession also affects the vertical reference. Figure 2-7 shows the action of a free gyro at the Equator. In its starting position, shown at 0600 hours on the Equator, the spin axis is horizontal and points in an easterly direction. If the earth is viewed from a position in space near the North Pole, it turns counterclockwise at the rate of one revolution every 24 hours, carrying the gyro around with it.

1. To an observer in space, the spin axis maintains its original direction in space because of gyroscopic inertia. To an observer on the earth, stationed where the gyro is mounted, the spin axis appears to tilt at a slow, steady rate.

2. At the end of 3 hours, the spin axis has tilted up 45° with respect to its original horizontal position.

3. After 6 hours, the spin axis has tilted 90° and is in a vertical position.

4. At the end of 12 hours, the spin axis is again horizontal but pointing west; after 24 hours, the spin axis is back where it started—horizontal and pointing east.

Section III. GYROSCOPIC INSTRUMENT POWER SOURCE

2-9. General

Aircraft use either vacuum or electrical power to keep the rotors of gyroscopic instruments rotating continuously. Vacuum operated gyros are reliable to approximately 30,000 feet and at temperatures down to about —35° Fahrenheit. Electrically operated gyros operate satisfactorily at altitudes exceeding 40,000 feet and at temperatures as low as —65° Fahrenheit.

2-10. Vacuum Driven Gyroscope

a. Operation. Vacuum driven gyroscopes are rotated by a stream of air striking buckets recessed in the rim of the rotor (B, fig. 2-9). This stream of air is created by reducing the pressure within the instrument case by means of an engine-driven vacuum pump. As the pressure within the case is reduced, outside atmospheric pressure forces air into the instrument case through a filter. An air nozzle connected to the filter is adjusted so that a stream of air will strike the rotor buckets at the proper position to cause the rotor to spin. The speed of the rotor may vary from 10,000 to 18,000 rpm, depending upon the design of the instruments.

b. Vacuum Source (fig. 2-8). The engine-driven vacuum pump normally used on aircraft gives a maximum vacuum of 10 inches of mercury (Hg) at normal engine operating speeds. This amount of vacuum is in excess of that needed to run the instruments, so a relief valve is installed to provide the desired vacuum. Check valves and pressure relief valves are installed in the lines to the instrument to eliminate the possibility of excessive back pressure if the engine backfires. Some multiengine aircraft have vacuum pumps on more than one engine, so that if either a pump or an engine fails, vacuum will not be interrupted. Single-engine aircraft do not have an alternate source. However, a windmilling engine at gliding speed will provide adequate vacuum for instrument operation.

c. Vacuum Gage. A vacuum gage located on the aircraft instrument panel is provided to indicate the applied suction. It indicates the

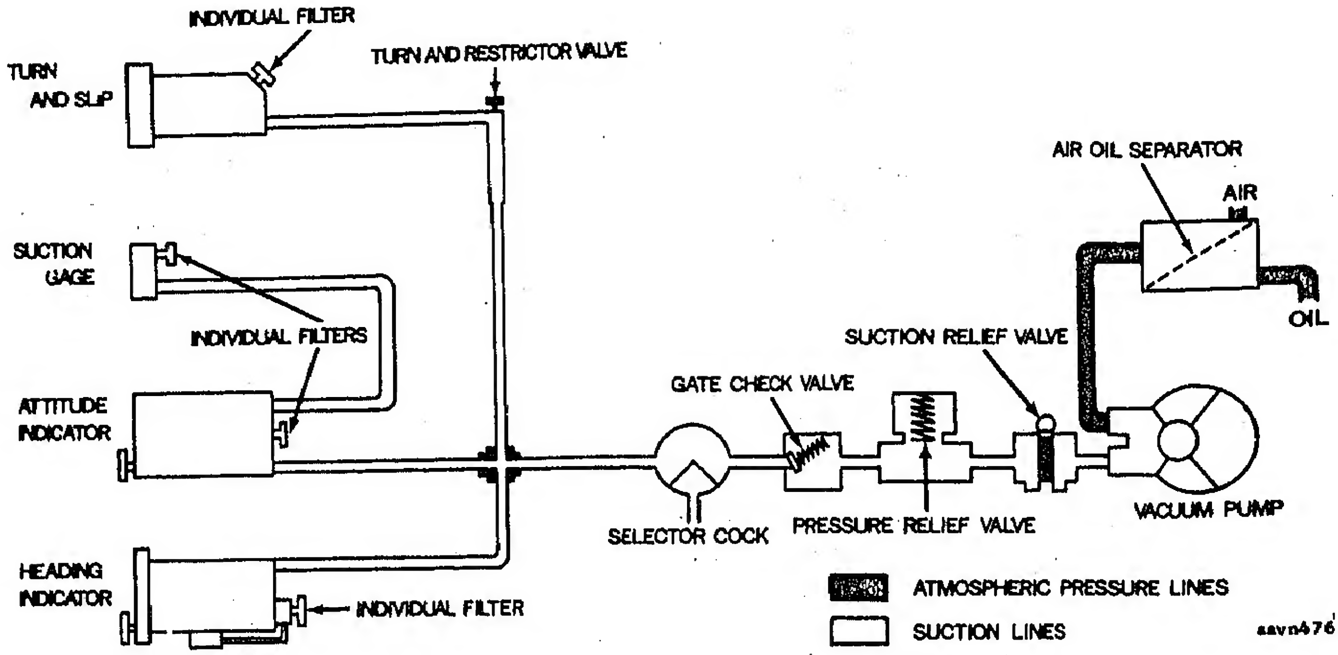


Figure 2-8. Vacuum system with individual air filters.

differential pressure between the atmospheric pressure and the pressure in the line created by the vacuum pump. It is read in inches Hg. For example, if atmospheric pressure is standard (29.92 inches Hg) and the pressure in the line is 25.92 inches Hg, the vacuum gage will indicate a reading of 4 inches Hg.

(1) The suction required to operate the vacuum driven attitude indicator and directional gyro is from 3.75 inches Hg to 4.25 Hg, with 4 inches Hg the optimum.

(2) The vacuum driven turn-and-slip indicator can operate with vacuum from 1.8 inches Hg to 2.1 inches Hg; however, 1.9 inches Hg is the desired vacuum. This vacuum condition is accomplished by a restrictor valve placed in the line leading to the instrument. The aviator does not know the amount of suction applied to the turn-and-slip indicator under normal conditions since the vacuum gage is connected ahead of the restrictor valve to the indicator. However, he should realize that if the vacuum in the main line falls below that required for the other gyro instruments, the turn-and-slip indicator will still be usable with a vacuum of 1.8 inches Hg.

2-11. Electrically Driven Gyroscopes

In electrically driven gyroscopes, the rotor and stator of an electric motor are enclosed in a gyro housing and become, in effect, the gyro. The gyro or rotor is operated on current supplied from the aircraft electrical system. An advantage of this system is that the case of the instrument can be hermetically sealed. This eliminates the danger of moisture condensation and keeps out sand, dust, salt, and fungus. When the gyro reaches operating speed, enough heat is generated to keep the motor lubricant solvent, even at altitudes where the outside air temperature is extremely low.

Section IV. GYRO HEADING INDICATOR

2-12. General

The gyro heading indicator (fig. 2-9) is fundamentally a mechanical instrument designed to facilitate the use of the magnetic compass. Errors in the magnetic compass are numerous (para. 2-5), making straight flight and turns to headings difficult, particularly in turbulent air. The gyro heading indicator tends to eliminate these errors; however, it is not a compass and must be set and periodically checked with reference to the magnetic compass or some other heading source. The calibrations on the card of the gyro heading indicator provide clear and accurate points of reference in flying headings.

2-13. Operation and Construction

The operation of the gyro heading indicator depends upon the gyroscopic principle of *rigidity in space.* A circular compass card is fixed to the vertical gimbal at right angles to the plane of the rotor. The rotor (B, fig. 2-9) turns in the vertical plane, but during turns in flight the rotor may deviate from the vertical plane of rotation. The erecting mechanism quickly returns the rotor to its normal plane of rotation. Since the rotor remains rigid in space, the points on the card hold the same position in space relative to the vertical plane —the case simply revolves about the card. The normal limits of operation of the instrument are 55° of pitch and 55° of bank.

a. Erecting Mechanism. During flight, deviations from the vertical plane cause the rotor to precess (para. 2-8*b*). To compensate for this precession, and to provide better airflow distribution on the buckets, the air is divided by two parallel jets at the tip of the nozzle (B, fig. 2-9). When the rotor is perpendicular or in its normal rotating plane, each jet strikes the buckets at points equidistant from the center of the buckets. If the gyro precesses, both jets will strike one side of the buckets and cause the plane of the rotor to again become parallel to the flow of air from the jets.

b. Adjustment. The heading indicator can be adjusted by pushing in on the caging knob to mesh pinion and ring gears (C, fig. 2-9), thereby permitting rotation of the vertical gimbal and card. Rotation of the vertical gimbal and card is accomplished by means of friction between rubber and metal rings.

c. Caging Arm. When the vertical gimbal is engaged, the gyro is no longer universal. Turning the caging knob tends to precess the rotor from the vertical plane. Such precession, however, is restricted by a caging arm attached to the vertical gimbal ring. If the rotor plane parallels the base of the case, the vertical gimbal card tends to spin with the rotor. The caging arm prevents this by serving as a stop.

d. Spinning Card. When the horizontal gimbal touches the stop, precessional force causes the card to spin rapidly. The spinning can be stopped by caging and uncaging the instrument.

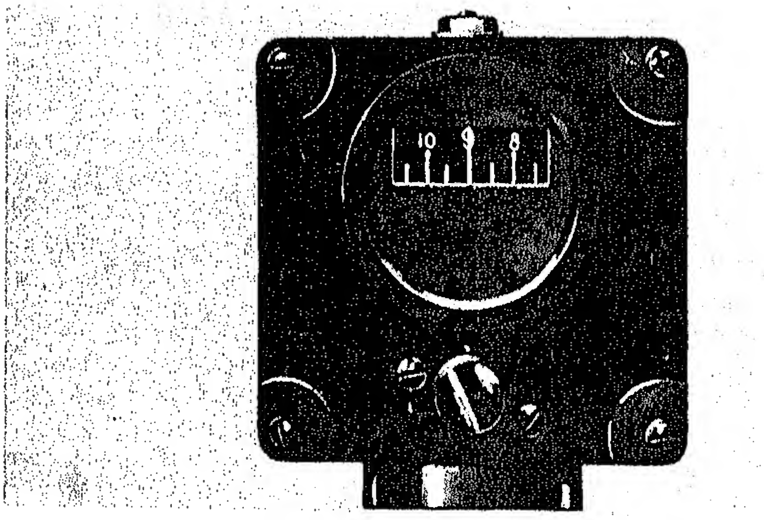
e. Caging. During maneuvers which exceed the limits of the instrument, the gyro should be caged. A great deal of force is applied to the bearings if the limits are exceeded and the gyro is tumbled. Frequent aerobatic flights with the instrument uncaged will shorten the life of the gyro unit.

2-14. Setting the Heading Indicator

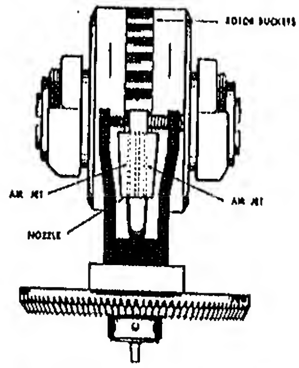
The heading indicator should be set with reference to the magnetic compass by rotating the indicator face with the caging knob. When uncaging, care must be taken to pull the caging knob straight out.

a. Precessing Errors. The heading indicator must be periodically checked (approximately every 15 minutes) since real and apparent precession (para. 2-8*b*) will induce heading errors.

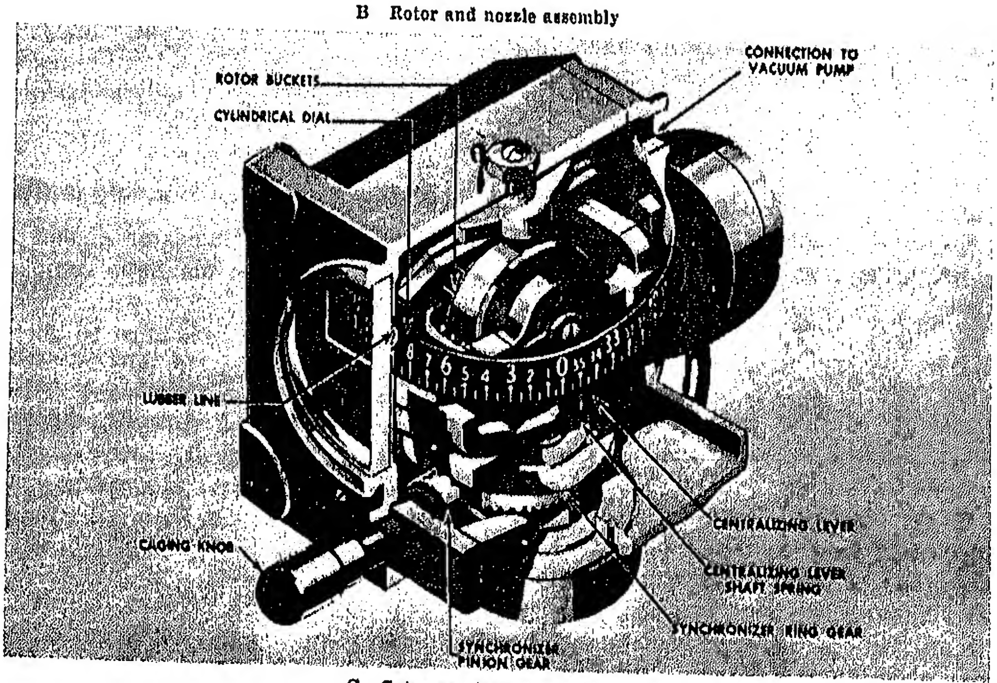
b. Limit of Error. An error of more than 3° in a 15-minute period is considered excessive and should be entered on the Aircraft Inspection and Maintenance Record.



A Indicator face



B Rotor and nozzle assembly



C Cutaway view

Figure 2-9. The vacuum driven gyro heading indicator.

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Section V. ATTITUDE INDICATORS

2-15. General

The attitude indicator, with its miniature aircraft and horizon bar, is the only instrument that protrays the actual flight attitude of the aircraft. It provides instantaneous indications of the smallest change in attitude. It has no lead or lag and is very reliable if properly maintained. Since the vacuum driven attitude indicator differs in many ways from the electrical attitude indicator, they will be discussed separately in this section.

2-16. Vacuum Driven

a. Construction. The horizon bar is attached to a gyroscope so that the horizon bar remains parallel to the natural horizon, thus establishing a level reference plane inside the aircraft. The basic mechanism in the attitude indicator is the gyro, a rotor wheel mounted inside an airtight housing. The rotor and housing (B, fig. 2-10) are mounted so that the rotor spins in a horizontal plane about a vertical axis. The rotor is supported at each end by five ball bearings. The rotor housing is pivoted laterally inside a gimbal which in turn is pivoted fore and aft to the airtight cylindrical instrument case. The lower part of the rotor housing is a hollow chamber containing four holes (ports), each of which is half-covered by a free-hanging, pendulous vane. The chamber containing the pendulous vanes (C, fig. 2-10) is the erecting mechanism of the suction attitude indicator. The horizon bar is linked to the gyro by a lever pivoted at one end to the horizontal gimbal ring and in the center to the gyro housing by a connecting pin. The horizon bar is attached near the end of the lever in order to be visible across the face of the instrument. The caging mechanism consists of a caging knob and of projecting rings which rotate in opposite directions around the inside of the case of the instrument when the knob is turned.

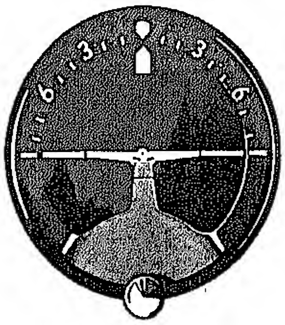
b. Operation.

(1) *Application of gyroscopic properties.* The gyroscopic property of *rigidity in space* establishes a reference plane within the aircraft, and that of *precession* maintains the vertical position of the axis. When the rotor has tilted from the vertical axis, the erecting mechanism exerts pressure against the rotor housing and precesses the gyro back to the vertical axis.

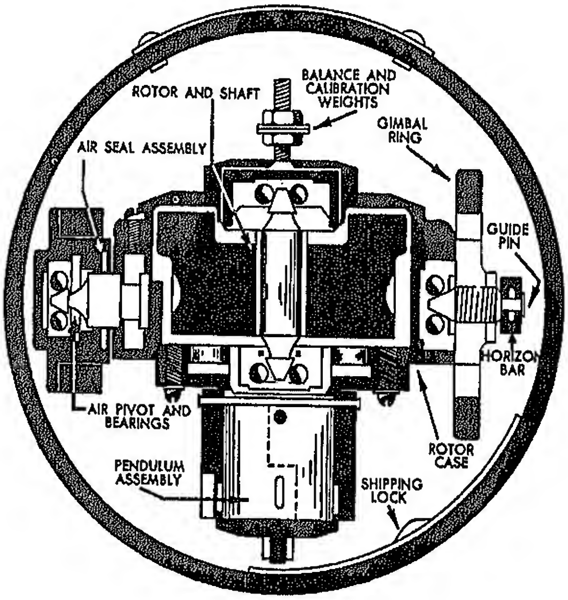
(2) *Airstream action.* Air enters the attitude indicator case through a filter and passes through an air bearing directly into the hollow passageway of the gimbal ring. From the gimbal ring the airflow enters the rotor housing through another air bearing. This airstream through the instrument spins the gyro and operates the erecting mechanism. Two jet openings in the rotor housing direct the airstream against the rotor wheel buckets, causing the rotor to spin counterclockwise at approximately 15,000 rpm. After turning the rotor, the air flows through holes into the instrument case, thus completing the cycle.

★(3) *Pressure differential.* For allowable vacuum limits, see appropriate 55-series TM.

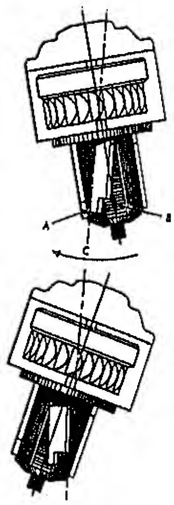
(4) *The erecting mechanism.* The erecting mechanism consists of the lower part of the rotor housing with its four openings (ports). Hanging freely and operating in pairs, each pendulous vane covers one-half of each port. When the gyro is tilted from the vertical axis, the pendulous vanes remain vertical; this causes one port to be opened and the opposite one to be closed. As a result, the escaping air through one port is cut off, while that through the open port increases in volume. This unequal escape of air causes the gyro to precess back to the vertical.



A Indicator face



B Rotor assembly



C Action of the pendulous vanes

Figure 2-10. The suction driven (vacuum) attitude indicator.

c. Limits for Caging and Uncaging the Attitude Indicator. The attitude indicator should be caged if its limits are to be exceeded, despite the fact that flying with the instrument caged causes excessive wear. When the bank of the aircraft is greater than 110° or the pitch angle greater than 70°, the rotor housing contacts stops on the instrument case, and extreme precession results. These stops prevent complete rotation of the rotor housing around the gyro assembly and also prevent destruction of the linkage system.

(1) *Tumbling.* The instrument "tumbles" when the rotor housing hits the stops. Tumbling is recognized by the rapid displacement of the horizon bar. The erection mechanism restores the rotor to its normal position gradually, or it can be reset by the caging-uncaging method. Indications of the instrument depend upon the position of the universally mounted gyro. If uncaged in an unlevel flight attitude, the gyro would remain in an unlevel plane except for the action of the erecting mechanism. Therefore, the attitude indicator should be uncaged only in a level flight attitude, and should be *fully* uncaged.

(2) *Errors.* Errors of the attitude indicator are minor and seldom exceed 3° or 4° of pitch or bank. Some of the common causes of errors are friction, unbalance, faulty construction, dirt, worn bearings, and clogged filter. However, errors do occur in attitude indicators which are in good condition, due to the pendulous vanes being swung from their vertical position by aerodynamic forces in turns, skidding flight, and acceleration or deceleration. This swinging of the vanes causes unequal escape of air from the ports, which causes the gyro to precess from the normal plane of rotation.

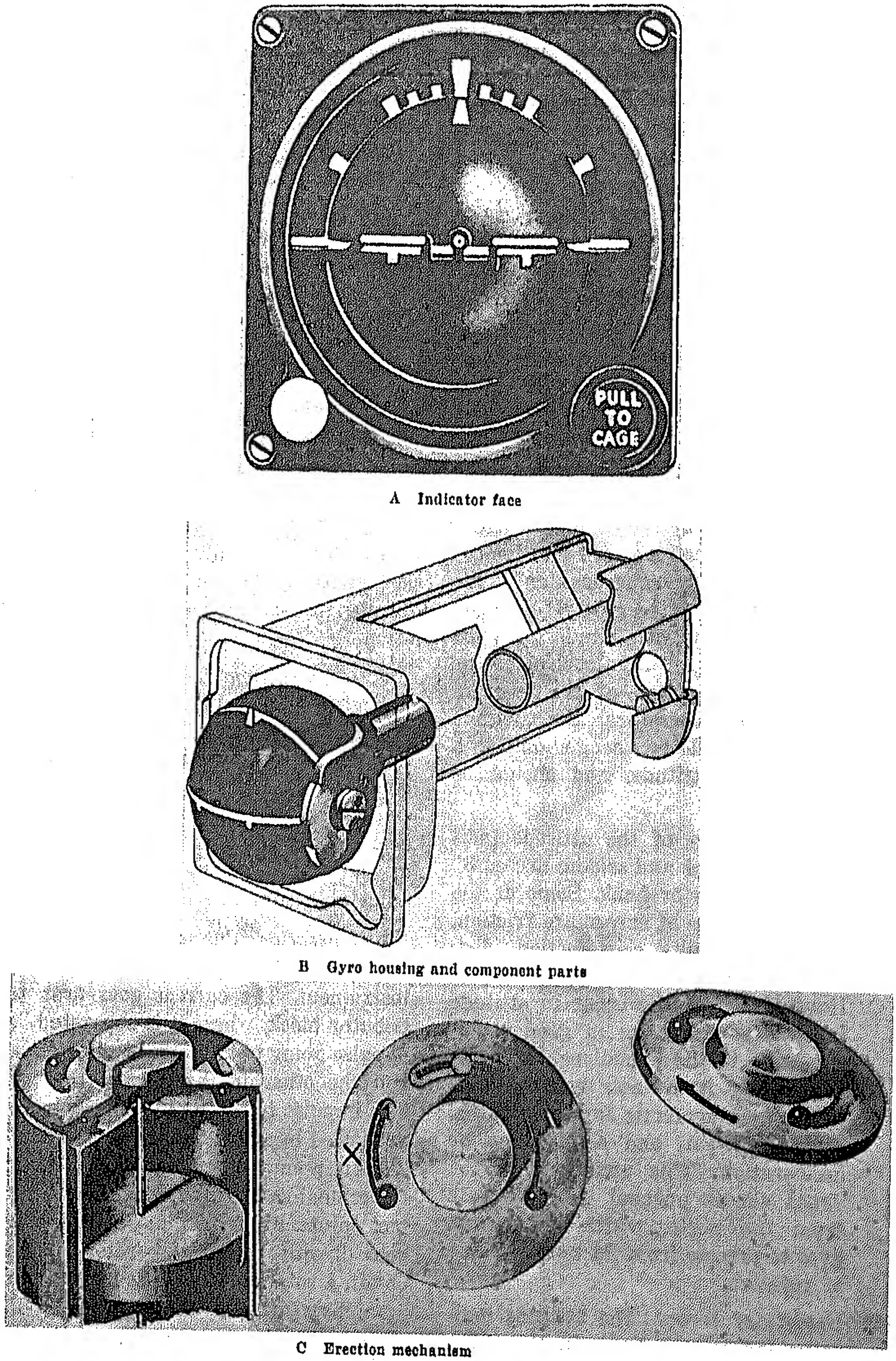
(3) *Results of errors.* The attitude indicator indicates a bank in the opposite direction of a skid, when the aircraft returns to straight-and-level flight. Acceleration causes the erecting mechanism to move the horizon bar downward, and the aviator tends to correct his aircraft attitude by lowering the nose. Deceleration has the opposite effect and the aviator tends to climb the aircraft. Both of the errors are proportional to the amount of acceleration or deceleration and the elapsed time while accelerating or decelerating. Precession of the gyro in a turn causes erroneous pitch and bank indications, but these are cancelled by the end of a 360° turn.

2-17. The J-8 Electrically Driven Attitude Indicator

The J-8 electrically driven attitude indicator is similar to the vacuum driven attitude indicator in construction and principle of operation.

a. Construction. The J-8 electric attitude indicator (fig. 2-11) has a vertical-seeking gyro; i.e., the axis of rotation tends to point toward the center of the earth or perpendicular to the earth's surface. This instrument includes a gyro case, a gyro rotor mounted inside a sphere, an OFF flag, a ball erecting mechanism, a manual caging device, and an adjustable miniature aircraft.

b. Operation. Current is fed into the indicator through a connection at the rear of the instrument. The current goes first to a distributor block, where it is separated, with one impulse going to the rotor of the gyro assembly and the other to the rear of the gyro case. The impulse to the rotor of the gyro assembly is carried by wires to each side of the gimbal. At this point, the current is fed directly into the gimbal shaft through five low-friction contact points. From the gimbal shaft, the current goes directly to the gyro rotor, causing it to obtain a rotation of at least 21,000 rpm within 3 minutes after power is applied. The gyro should then be in a nearly vertical position with relation to the surface of the earth. An



A Indicator face

B Gyro housing and component parts

C Erection mechanism

Figure 2-11. The J-8 electric attitude indicator.

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OFF flag, visible through the glass on the face of the instrument indicates that the gyro is not operating properly.

c. Positioning the Gyro. The gyro positions itself by means of a ball erecting mechanism (C, fig. 2-11). A circular magnet, rigidly fixed on the top end of the gyro rotor shaft, rotates at the same speed as the rotor and shaft (21,-000 rpm).

(1) *Operation and function of the plate and collar.* Supported by ball bearings and surrounding the rotating magnet is a plate with a collar. This plate is free to rotate but is not connected to the gyro rotor shaft. By varying the amount of magnetism in the rotating magnet, the speed of the plate and the collar surrounding it can be controlled. Increasing the magnetic force increases the speed of the plate and collar. The desired speed of the collar is 44 to 48 rpm. The function of the rotating plate and collar is to carry two steel balls around the top of the gyro. These balls act as the erection mechanism.

(2) *Operation of the erection mechanism.* The erection mechanism (C, fig. 2-11) operates on the principle of precession. As long as the gyro is vertical the two balls rotate at 44 and 48 rpm inside the slots in the plate at the top of the gyro. However, if the gyro becomes tilted, the balls slow down at some positions and speed up at others. As the balls pass the high points of the gyro (tilted), they are rolled forward rapidly by gravity, spending little time on the "downhill" side of the gyro. Reaching the "uphill" side of the gyro, however, the balls are returned by gravity to the trailing ends of the slots. Since the balls spend more time on the "uphill" side of the gyro, more weight is exerted in this position and a type of precessional force is established.

(3) *Precessional force.* The force exerted in the "uphill" position precesses the gyro. Since precessional force acts 90° in the direction of rotation ahead of, and in the same direction as, the original force applied, the result is the same as if the force were applied at the high spot of the gyro.

d. Caging the Gyro. The gyro of the attitude indicator may be manually caged (A, fig. 2-11) by means of a gyro centering device, operated by the caging knob at the lower right front of the instrument. By providing springs of different compression resistance and a set of cams and followers in the caging mechanism, the gyro may be centered first about the roll axis and then about the pitch axis, whether the gyro rotor is spinning or at rest. The manual caging device serves a twofold purpose—(1) it provides a means for quickly erecting the gyro and (2) it provides a means of erecting the gyro when in-flight errors are induced by turns or acrobatics. Since the indicator cages to the attitude of the aircraft and not to the true vertical, the instrument should never be caged to correct in-flight errors unless the aircraft is in straight-and-level flight. To determine whether the caging mechanism has completely released, push the caging knob against the instrument case after it has been released. If further travel is evidenced or precession of the gyro is noted, the caging mechanism is not operating properly.

e. The Miniature Aircraft Device. A device representing a miniature aircraft is suspended at each side of the instrument and is free to travel up and down across the face of the instrument. The relationship between the miniature aircraft device and the horizon bar indicates the attitude of the aircraft. The miniature aircraft device can be adjusted to allow for load and airspeed changes which affect the angle of attack. It may be adjusted vertically by turning a knob at the lower left corner of the instrument. This knob operates an endless chain over pulleys, which moves the miniature aircraft device up and down as the knob is rotated.

f. Presentation of Indications. The pitch attitude of the aircraft is indicated within a range of 27° in climb and dive by displacing

the horizon bar with respect to the adjustable miniature aircraft device.

(1) *Operation of the horizon bar.* The horizon bar is mounted to the gyro gimbal in such a manner that it can be centered by the gyro through a pin-and-fork arrangement. Raising the nose of the aircraft causes the horizon bar to go down. At the limits of travel of the horizon bar, 27° up or down, the fork is disengaged from the pin, and the gyro, with sphere attached, is free to continue its movement. The bar does not return to neutral because just before the fork and pin are disengaged, a cam contacts the bar and holds it stationary at the limit of its travel. When the aircraft exceeds 27° of pitch change and the bar is no longer moving, the sphere (B, fig. 2-11) becomes the new reference. A continued increase in climb or dive angle which approaches vertical attitude is indicated by the word "climb" or "dive" on the sphere. When the aircraft approaches 90° in pitch, as it does during a loop, controlled precession is accomplished by a mechanical stop on one side of the gyro rotor gimbal. The gyro strikes this stop at approximately 90° from level flight. When the stop is reached, the force of the gyro is directed so as to precess 180°. This causes the horizon bar to turn over completely. For example, in a loop maneuver, controlled precession would occur twice—once when going straight up and once when coming straight down. When the aircraft is again flown within 27° of level flight, the bar is completely operational. (The type of controlled precession described should not be confused with tumbling or spilling of the instrument.)

(2) *Determining whether the aircraft is right-side-up or inverted.* Two methods can be used to determine whether the aircraft is right-side-up or inverted. If right-side-up, the two projections on the horizon bar will extend down (as viewed normally), and the banking indexes at the top of the instrument will be adjacent to the reference marks on the case. If inverted, the projections on the horizon bar will extend up (as viewed by the aviator), and the banking index will be on the opposite side of the case from the reference marks. The banking index is attached directly to the gyro gimbal and consequently will assume the same position, in relation to the earth's surface, that the gyro assumes. Actually, in a roll the gyro and banking index remain relatively stationary while the instrument case rolls around them.

g. Errors in the Electric Attitude Indicator. Since the electric attitude indicator is hermetically sealed, it is less subject to friction errors found in vacuum driven indicators. However, it is subject to in-flight errors caused by forces in turns, unbalanced flight (skidding and slipping), and acceleration or deceleration. The reaction is generally the same as that of the vacuum driven indicator (para. 2-16*c*(2), (3)).

2-18. The Lear Model 4005G Electrically Driven Attitude Indicator

The design of the Lear model 4005G indicator (fig. 2-12) is an improvement over the J-8 indicator. This indicator is similar in operation to the J-8 except that it adjusts the horizon bar for pitch trim instead of adjusting the miniature aircraft.

a. Miniature Aircraft Device Adjustment Knob. The miniature aircraft device adjustment knob is located on the lower right side of the indicator case. This knob is used to adjust the horizon line up or down with respect to the miniature airplane and to compensate for the aviator's different lines of vision.

b. Roll Trim Knob. The roll trim knob is located on the upper right side of the instru-

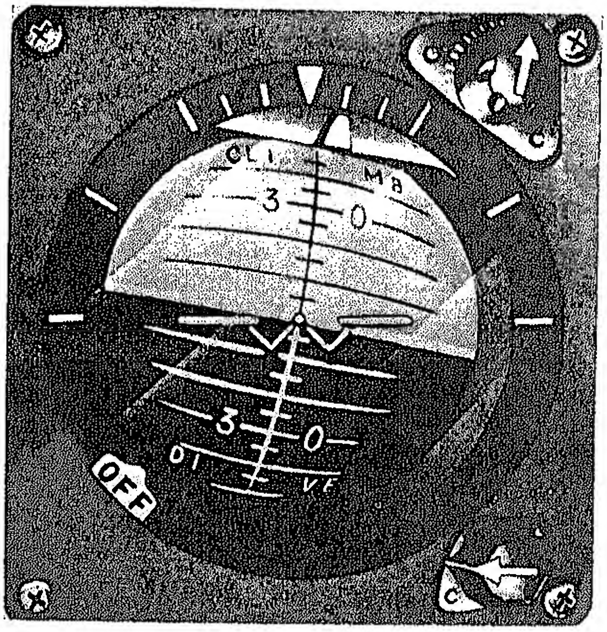

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Figure 2-12. The Lear model electric attitude indicator 4005G.

ment case. This knob positions the sphere with respect to the 10°, 20°, 30°, 60°, and 90° bank indications.

c. *Presentation of Indications.*

(1) *Sphere.* The sphere has a white background with black arcs above the zero pitch line. These arcs are spaced at 5° intervals, with the long arcs indicating each 10° of pitch. Pitch angles of 30° and 60° are also indicated by numerals. CLIMB or DIVE markings are centered on the 45° pitch circle.

(2) *Angle of bank.* The angle of bank is indicated by the position of the bank index pointer relative to the 10°, 20°, 30°, 60°, and 90° markings on the case, and by orientation of the miniature aircraft with respect to the sphere in the background.

d. *OFF Flag.* The OFF flag on the instrument warns of power failure. The warning flag should disappear approximately 2 minutes after turning on the power. Pulling the circuit breaker on the AC phase or any DC control circuit should cause the warning flag to appear immediately.

e. *Turn and Acceleration Errors.* Turn and acceleration errors have been reduced in the Lear model 4005G indicator by use of an improved displacement gyro (MD-1) and the MC-1 rate-switching gyro. Whenever the rate of turn is greater than 15° per minute, the MC-1 rate-switching gyroscope actuates relays to stop erection of the MD-1 displacement gyro (either in roll or in roll and pitch) for the duration of the turn, thereby virtually eliminating the turn error.

2-19. ID-882 Navigation Attitude Indicator

a. *General.* A newer type of attitude indicator is the ID-882 (fig. 2-13). This indicator is a part of the AN/ASN-33 integrated flight system discussed in TM 1-225. This indicator presents basic attitude, glide slope, and steering pointer information. The steering pointer aids the aviator in turning to or maintaining preselected headings. The horizon disc is grey above and black below, representing sky and ground respectively. Red warning flags are activated when information from the glide slope receiver, localizer receiver, steering computer, or vertical gyro is unreliable, or when the individual components have failed. The left knob adjusts the airplane pitch bar. The right knob selects either the ILS or heading (HDG) function.

b. *Functioning.* The pitch bar and horizon line are driven by servos. The warning flags and steering pointer are standard meter movements.

c. *Bank Pointer and Horizon Line.* The bank pointer and horizon line (fig. 2-14) operate together. The bank pointer indicates the amount of bank read from the 10°, 20°, 30°, and 60° graduations at the top of the horizon disc. The horizon line indicates the roll attitude of the aircraft, independent of pitch. The bank pointer and horizon disc cover the complete 360° range of indication.

d. *Pitch Bar and Pitch Trim.* The pitch bar (fig. 2-15) moves in a vertical plane above and

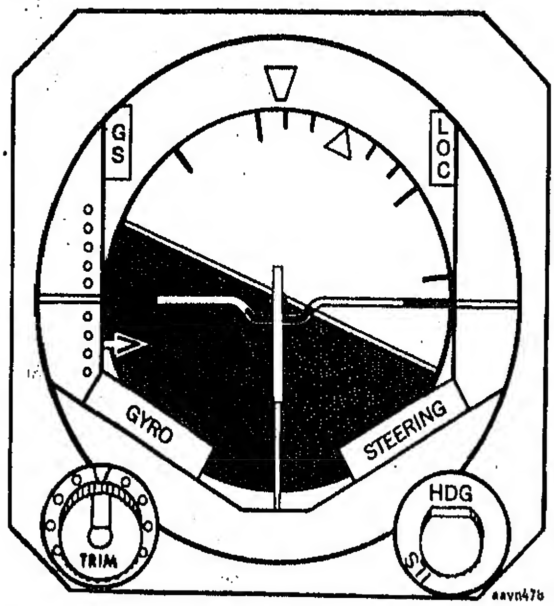


Figure 2-13. Navigation attitude indicator ID-882.

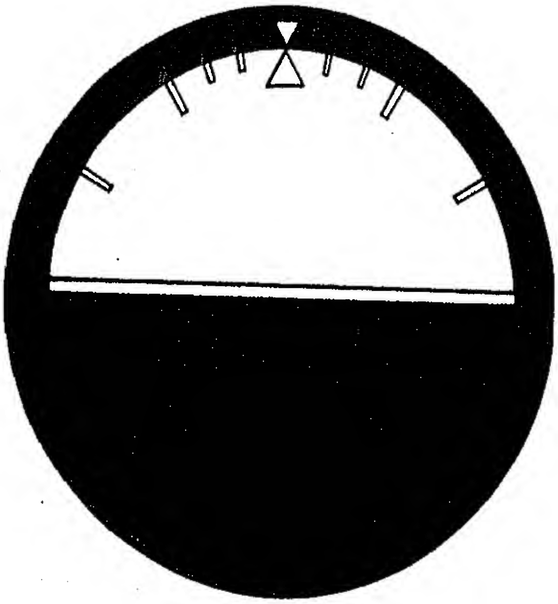


Figure 2-14. Bank pointer and horizon line.

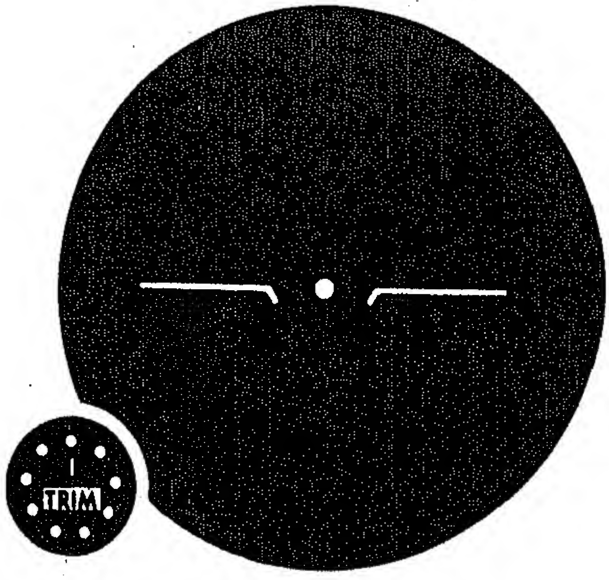


Figure 2-15. Pitch bar and pitch trim knob.

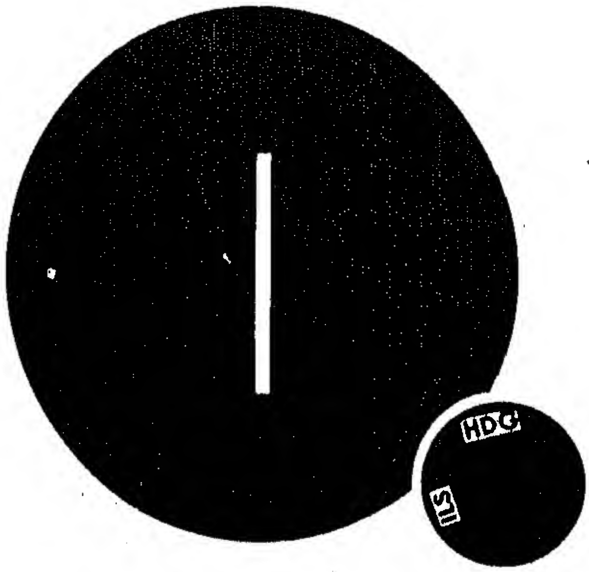


Figure 2-16. Steering pointer and HDG-ILS switch.

below the center line of the instrument to show a nose-up or nose-down attitude. The pitch trim knob (fig. 2-15) centers the bar at the desired flight attitude in the HDG function. In the ILS function, pitch trim is preset to the aircraft's normal approach attitude. The maximum pitch range is 85° above or below the horizon. The pitch trim adjustment in HDG has a range of +20° to —15° with 5° markings on the knob.

e. Steering Pointer and HDG-ILS Switch. The position of the steering pointer (fig. 2-16) is the bank command. The HDG-ILS switch (fig. 2-16) selects the flight mode. In HDG, the pointer is actuated by combined

heading error (difference in aircraft heading and heading selected with heading marker on ID-883 course indicator (fig. 2-22)) and bank information. In ILS, the points actuated by combined heading error, bank information, and instrument landing system localizer signals. In either case, a right deflection is a command to bank right; left deflection is a command to bank left.

f. Warning Flags. When the STEERING flag (fig. 2-17) is visible, computer power is out. When the GYRO flag (fig. 2-17) is visible, the roll or pitch attitude indicator circuits are not operating properly.

Note. Bank information for the steering pointer is not supplied from the attitude indicator gyro. Therefore, the GYRO flag would not indicate failure of the steering pointer.

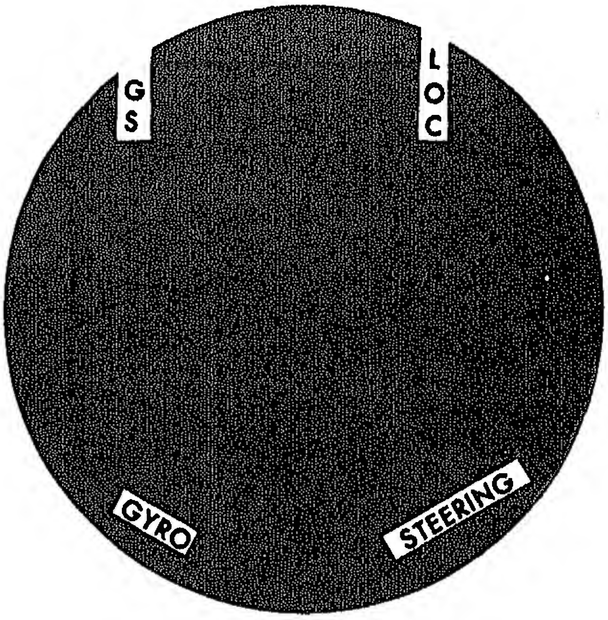


Figure 2-17. Warning flags.

Section VI. TURN-AND-SLIP INDICATOR

2-20. Turn-and-Slip Indicator

The turn-and-slip indicator (A, fig. 2-18) is a combination of two instruments, a turn needle and a ball. The turn needle depends on gyroscopic precession for its indications; the ball is actuated by natural forces. The gyroscope of the turn needle may be either vacuum or electrically driven. The principles of operation are the same.

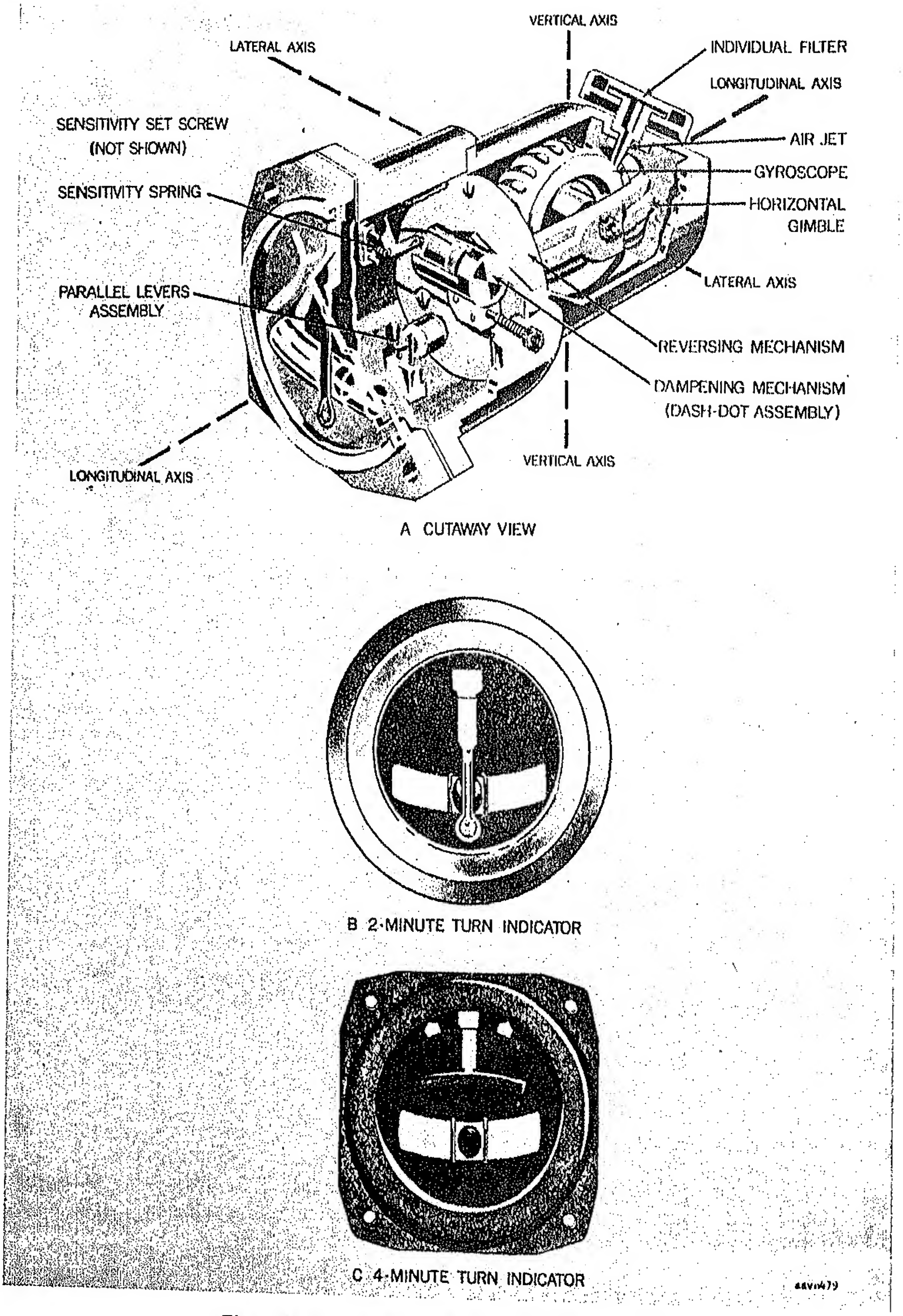
2-21. The Turn Needle

a. Construction. The turn needle is actuated by a gyroscope. A gimbal ring encircles the gyro in a horizontal plane and is pivoted fore and aft in the instrument case. The gyroscope spins around a lateral axis mounted to the horizontal gimbal. This permits the gyroscope to rotate freely about both the lateral and longitudinal axis (A, fig. 2-18), but restricts its rotation about the vertical axis.

(1) *Round disc.* A round disc is attached to the gyroscope assembly. Positioned on this disc is a cam with projecting lever. This lever extends in a plane parallel to the longitudinal axis of the instrument case. It deflects the turn needle in a direction opposite to that of precession of the gyroscope assembly.

(2) *Sensitivity spring.* A sensitivity spring (A, fig. 2-18) is attached at one end to the case and at the other end to the gyro assembly. This spring makes it possible to calibrate the instrument for a given rate of turn. It also holds the gyro assembly perpendicular to the instrument case as long as no force is applied about the vertical axis. The tension on the spring may be adjusted by a setscrew on the left-hand side of the case.

(3) *Dampening mechanism.* A dampening mechanism near the disc prevents excessive oscillation of the needle. This mechanism is composed of a cylinder, a piston, and a rod. The rod connects the piston to the gyro assembly. A small hole in the head of the cylinder may be adjusted in size by a setscrew on the righthand side of the case. This adjusts the dampen-



A CUTAWAY VIEW

B 2-MINUTE TURN INDICATOR

C 4-MINUTE TURN INDICATOR

Figure 2-18. Suction driven turn-and-slip indicator.

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ing effect of the needle.

(4) *Restrictor valve.* On the vacuum driven turn-and-slip indicator a restrictor valve is used to control the suction to the turn needle gyroscope. This valve is installed between the main suction line and the instrument, and limits the suction to 1.8 inches Hg to 2.1 inches Hg.

b. Operation. With gyroscope spinning at its normal operating speed, any turn of the aircraft will turn the instrument case of the turn-and-slip indicator. Since the horizontal gimbal containing the spinning gyroscope is attached to the instrument case, it will rotate around a vertical axis. This rotation will cause the gyroscope to precess, moving the horizontal gimbal and attached round disc. This movement of the round disc deflects the turn needle in the proper direction to indicate a turn. The amount of deflection is proportional to the rate of turn (number of degrees per second) of the aircraft. When the force of precession equals the spring tension, the turn needle gives a steady indication. The movement of the needle is cushioned and steadied by the dampening cylinder. In recovering from a turn, the gimbal is returned to its normal position by the spring tension, which forces the gimbal and thus the turn needle to its correct position. Stops are provided to limit the precession of the rotor assembly to 45° in either direction from the vertical.

c. Indicators. There are two types of turn-and-slip indicators. These differ in the amount of turn represented by a needle-width deflection. The 2-minute turn needle (B, fig. 2–18) is so-called since a one-needle width deflection represents a turn of 3° per second (2 minutes to complete a 360° turn). The 4-minute turn needle (C, fig. 2–18) is calibrated for higher performance aircraft so that a one-needle width deflection will represent a turn of 1½° per second (4 minutes to complete a turn of 360°).

2–22. The Ball

The ball part of the turn-and-slip indicator consists of a sealed, curved glass tube containing water-white kerosene and a black agate or common steel ball bearing which is free to move inside the tube. The fluid provides a dampening action and insures smooth and easy movement of the ball. The tube is curved so that the ball seeks the lowest point at its center. A small projection on the left end of the tube contains a bubble of air which compensates for expansion of the fluid during changes in temperature. Two strands of safety wire are wound around the glass tube as reference markers to indicate the correct position of the ball in the tube. The plate to which the tube is fastened and the reference wires are usually accented by luminous paint.

a. In Straight-and-Level Flight. During straight-and-level flight, the force of gravity causes the ball to rest in the lowest part of the tube.

b. In a Balanced Turn. In a balanced turn, the forces acting on the ball are gravity and centrifugal force. Since these forces are in balance, the ball remains in the center of the tube. When the forces acting on the ball become unbalanced, the ball moves away from the center of the tube.

c. In a Skid. In a skid, the rate of turn is too great for the angle of bank. The centrifugal force is excessive, and the resultant of centrifugal force and gravity is not opposite the midpoint between the reference markers, but toward the outside of the turn. Consequently, the ball moves in that direction. Correcting to balanced flight requires an increase of the bank or a decrease of the rate of turn, or both.

d. In a Slip. In a slip, the rate of turn is too slow for the angle of bank. There is not enough centrifugal force, and the resultant of centrifugal force and gravity causes the ball to move toward the inside of the turn. Correcting to balanced flight requires decreasing the bank or increasing the rate of turn, or both.

e. As a Balance Indicator. The ball instrument serves to check coordination. It is actually a "balance" indicator, because it indicates the relationship between the angle of bank and the rate of turn. It tells the quality of the turn—whether the aircraft has the correct angle of bank for its rate of turn.

Section VII. SLAVED GYRO COMPASS SYSTEMS

2-23. General

Slaved gyro compass systems (fig. 2-19) installed in Army aircraft include the AN/ASN-13, J-2, and MA-1. Each system is, in effect, a gyro-stabilized magnetic compass. The slaved gyro compass system may be operated as a magnetically slaved gyro compass over areas of the earth's surface where the earth's magnetic field of force is usable. Each system may also be operated as a free gyro heading indicator in areas where the earth's magnetic field is unusable (para. 2-3*b*).

a. Slaved Gyro Mode of Operation. In the slaved mode of operation, a direction-sensing device called a *flux valve* detects the angular position of the earth's magnetic field with respect to the aircraft. This information is fed to a drive unit used to aline the gyro. From the gyro a stabilized heading indication is presented to the aviator.

b. Free Gyro Mode of Operation. In the free mode of operation, the direction-sensing flux valve is disconnected from the system, and the gyro is used only as a heading reference indicator. The aviator must originally set the heading indicator to correspond to the aircraft heading. The aircraft heading can be obtained from a standby magnetic compass or by alinement with the runway, etc. Since the gyro is not slaved to the flux valve unit, the heading indicator is subject to drift. The aviator should periodically check the heading indications with those of his standby source of heading reference and reset if necessary.

2-24. Components

Essentially, each slaved gyro compass system consists of a compass transmitter, an amplifier, a directional gyro, a primary heading indicator, and normally a repeater heading indicator.

a. Compass Transmitter. The compass transmitter contains the flux valve unit, which is the direction-sensing device of the system. This unit detects the horizontal components (or lines of flux) of the earth's magnetic field and is suspended by a universal joint. The unit is weighted so that it normally maintains a horizontal plane. The universal suspension allows the flux valve to hang like a plumb bob and swing in a pendulous manner. The flux valve unit cannot rotate and is fixed to turn with the aircraft. Any change in direction by the aircraft results in a corresponding change of the flux valve unit in relation to the earth's magnetic field. This field of force induces an electrical voltage in the flux valve unit which is transmitted through the amplifier to the directional gyro control. Since the heading information is transmitted electrically to the gyro, the unit can be installed at a remote part of the aircraft (e.g., wingtip) where magnetic deviation is at a minimum. A mechanical compensator further reduces the deviation effect.

b. Amplifier. The amplifier is the coordinating and distributing center of the slaved gyro compass system. Its principal function is to increase the strength of the signals from the compass transmitter. Normally, the amplifier also serves as the power supply and junction box of the compass system.

c. Directional Gyro. The directional gyro maintains a constant directional reference by using the gyroscopic property of rigidity in space (para. 2-8*a*). The case of the directional gyro control unit rotates in azimuth about the directionally stabilized gyro as the aircraft turns. As the aircraft rotates about the gyro, the turn information is relayed to the primary heading indicator and the repeater indicator. The directional gyro maintains its reference to magnetic north by signals received from the remote compass transmitter. These signals operate a torque motor in the directional gyro control. The torque motor precesses the gyro unit until it is alined with the transmitter signal, thus slaving the gyro to the earth's magnetic meridian. The gyro is free to operate within 85° from the level flight attitude, both in pitch and bank. When these limits are exceeded, the gyro strikes mechanical stops. This causes erroneous indications

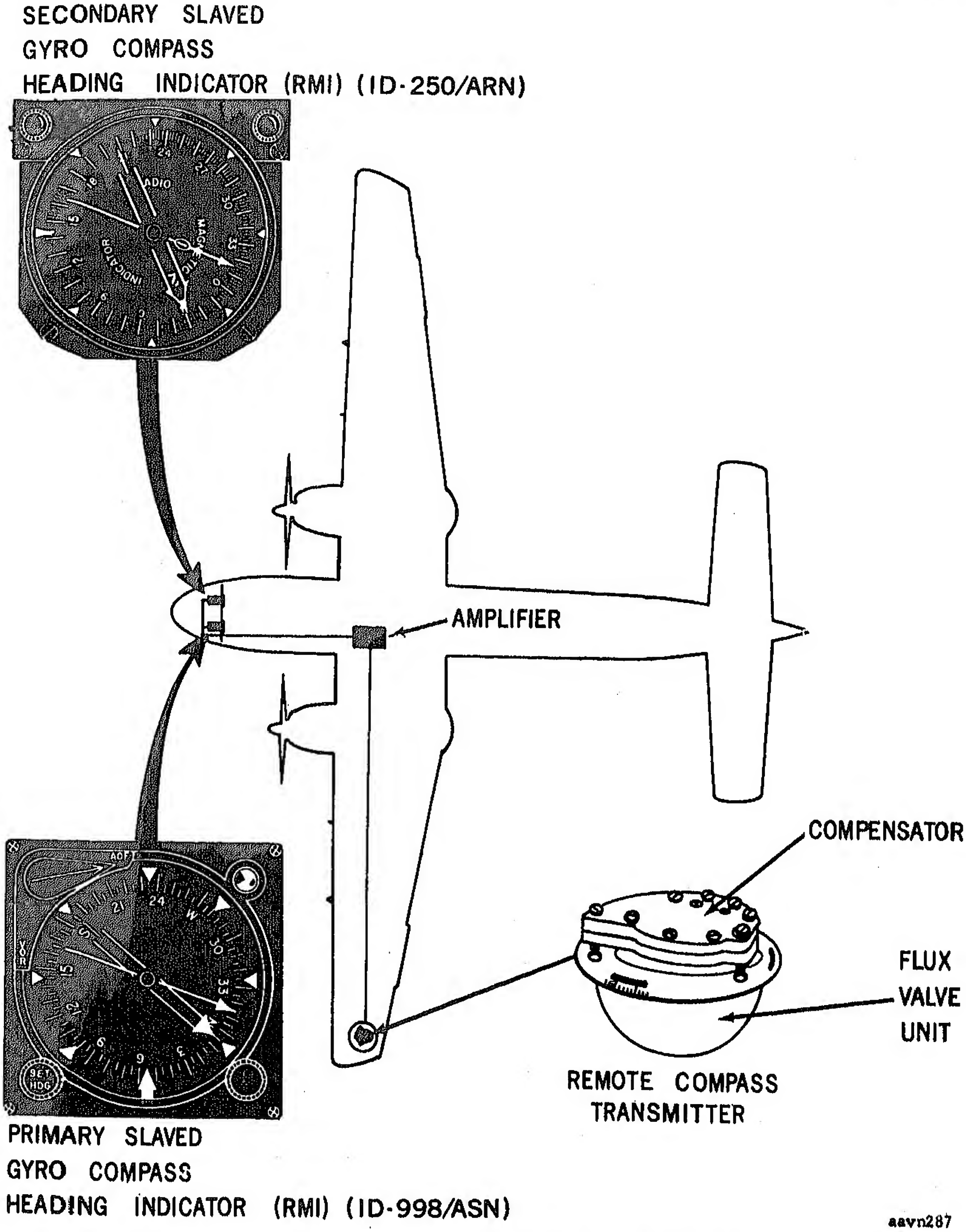

Figure 2-19. Components of a typical slaved gyro compass system.

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to appear on the heading indicators until the directional gyro is again slaved to the magnetic meridian. Induced errors may be as large as 5°; however, the gyro will erect fully in 5 minutes or less.

d. Heading Indicators. The heading indicators (para. 2-26 through 2-29) in gyro compass systems may be either *primary* or *repeater.*

(1) *Primary.* Some primary heading indicators have an annunciator window and a gyro synchronizing control knob. The annunciator window shows the direction in which the synchronizing knob should be rotated. If the gyro controls are not found on the primary heading indicator, they will be found on the gyro control panel, as in the MA-1 compass system.

(2) *Repeater.* The repeater dial may look exactly like the primary dial, but it merely repeats the indications on the primary indicator. The repeater indicator does not have a synchronizing knob.

2-25. Operation

Caution: **Failure to synchronize this compass system correctly has been a contributing factor to several aircraft accidents.**

a. AN/ASN-13 and J-2 Slaved Gyro Compass Systems Operation. In these two systems, the compass controls are located on the instruments. This control is a spring-loaded, push-to-set synchronizing knob marked with directional arrows, a dot (.) or a minus sign (—), and a plus sign (+). The ID-567/ASN heading indicator (fig. 2-21) is used with the AN/ASN-13 compass system; the ID-998/ASN heading indicator (fig. 2-19) is used with the J-2 compass system. To operate these systems, proceed as follows:

(1) *Slaved gyro mode.*

(*a*) *Starting procedure.*

1. Set the slaving cutout switch to the IN position.

2. Apply power to the compass system from the aircraft power supply.

3. Allow 2 to 3 minutes for the rotor of the gyro to reach operating speed.

(*b*) *Synchronizing procedure.* Although the compass system begins to synchronize automatically when power is applied, the indicator and flux valve should be manually synchronized before takeoff. Manual synchronization eliminates a long synchronization period. Synchronize the compass system as follows:

1. Observe the annunciator window. If the system is synchronized while the aircraft is on the ground, this window will appear blank. The system is synchronized in flight if the dot (.) or minus sign (—) and plus sign (+) appear *alternately.* Steady appearance of the dot (.), minus sign (—), or plus sign (+) indicates the need for synchronization.

2. If synchronization is necessary, depress and turn the synchronizing knob in the direction of the symbol which appears in the annunciator window (*1* above).

Caution: **Do not keep the synchronizing knob depressed more than 2 minutes.**

3. Check to see that the heading dial is indicating the known earth reference within 3°. The repeater heading indicator should agree with the primary heading indicator.

(*c*) *Operating procedure.* The heading indicators will furnish proper magnetic heading indications when the compass system is synchronized, provided the operating limits are not exceeded. To maintain flight on a constant heading, control the aircraft to keep the desired heading indication matched with the lubber line at the top of the indicator.

(2) *Free gyro mode.*

(*a*) *Starting procedure.*

1. Set the slaving cutout switch to the OUT position.

2. Apply power to the compass system from the aircraft power supply.

3. Allow 2 to 3 minutes for the rotor of the gyro to reach operating speed.

(b) *Alinement procedure.* Since synchronization between the indicator and the flux valve does not occur in free gyro operation, the heading dial must be manually alined before gyro operation. To aline—

1. Observe the heading indicated on the heading dial.

2. Depress and turn the synchronizing knob until the heading dial corresponds to the known heading reference.

***Caution:* Do not keep the synchronizing knob depressed more than 2 minutes.**

(c) *Operating procedures.* Since the gyro is not slaved to the earth's magnetic field in the free mode of operation, heading indications depend only on the ability of the gyro to maintain the orientation of its axes through gyroscopic principles. Thus, the gyro is subject to drift, making the heading dial indications inaccurate. To correct for this drift, periodically realine the heading dial ((b) above) to agree with known heading references. The heading indicator must be realined if the gyro operating limits of the indicator are exceeded (para. 2-24c).

b. MA-1 Compass System Operation. The controls for the MA-1 system are located on a separate control panel (fig. 2-20) that is normally mounted on the aircraft instrument panel. There is no ON-OFF switch on this panel and the compass system is energized as soon as the basic aircraft power is applied. A minimum of 1 minute warmup time should be allowed.

(1) *Slaved operation.*

(a) Set the control panel SLAVED-FREE switch to the SLAVED position.

(b) Check the position of the syncronization indicator (SYNC IND) meter pointer. An off-center pointer will require correction by means of the SET HDG switch as follows:

Pointer direction	*Set HDG switch to*
"L"	"R"
"R"	"L"

(c) Monitor the SYNC IND meter when synchronizing the compass with the SET HDG switch. When the SYNC IND meter pointer is centered, or close to center, the compass is synchronized. (Small deviations of the pointer from center will be corrected automatically by normal slaving.)

(d) Straight-and-level flight will not require further synchronizing and the aircraft heading will appear under the lubber line of the heading indicator. However, a series of turns may require repetition of steps (b) and (c) above to slave the compass rapidly.

(2) *Free operation.* Operation as a free gyro system requires the initial establishment of a known heading. This may be determined by a standby magnetic compass, runway alinement, etc. In flight, the heading may be determined from the magnetically slaved course if the change from SLAVED to FREE mode is made before the earth's magnetic field becomes unusable. To set up the compass for FREE operation, proceed as follows:

(a) Set the control panel SLAVED FREE switch to the FREE position.

(b) Set the LAT CONT knob to the NORTH or SOUTH setting which represents the hemisphere and latitude of the present position of the

aircraft. (This setting will transmit a counteracting force to oppose the apparent precession. The aviator should reset the latitude knob to correspond to the latitude of the aircraft after each 5° of change.)

(c) Compare the heading of the heading indicator with that of the known heading reference. Make the necessary heading corrections by driving the compass card with the SET HDG switch, as follows:

Compass repeater	*Set HDG switch to*
Left of desired heading	"R"
Right of desired heading	"L"

(d) In flight the heading indicator will reflect the heading of the aircraft with respect to the heading initially set by the aviator. If subsequent setting is necessary, follow steps (b) and (c) above.

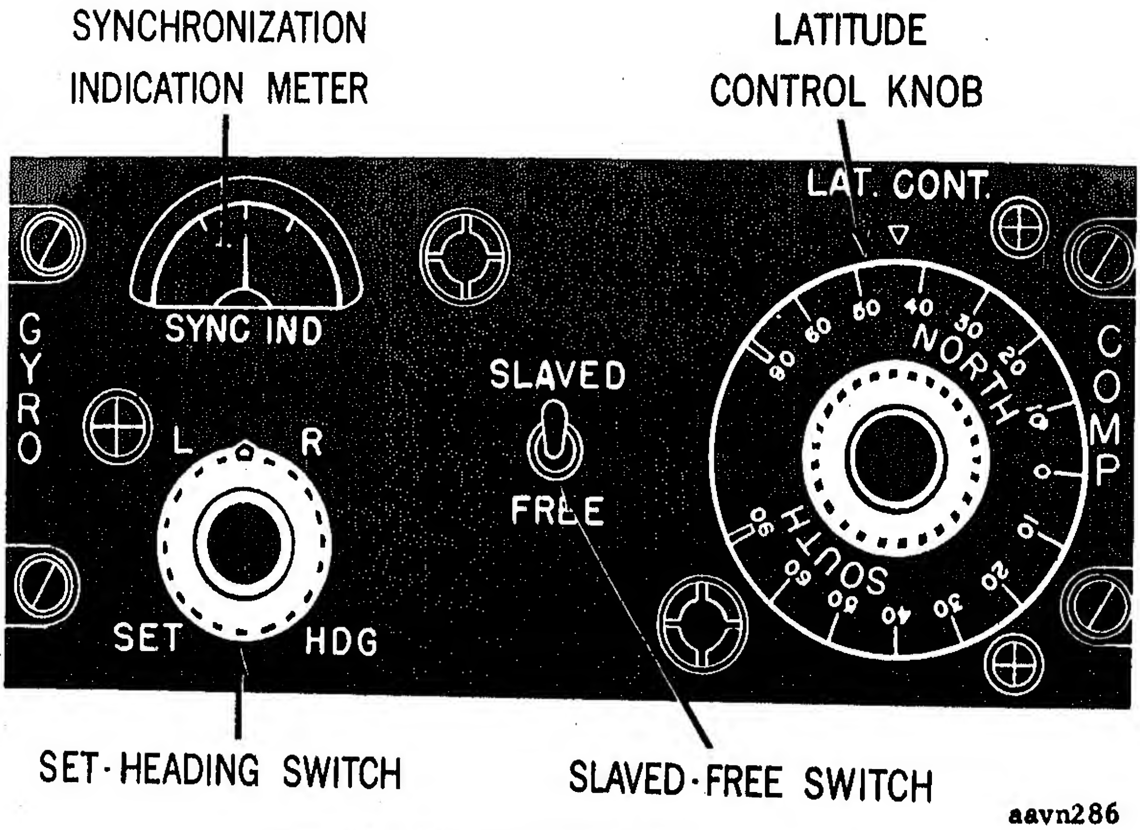

Figure 2-20. MA-1 gyro compass system control panel.

Section VIII. SLAVED GYRO MAGNETIC HEADING INDICATORS

2-26. Electric Heading Indicator ID-567/ASN

The heading indicator ID-567/ASN (fig. 2-21) is mechanically linked to an electrically driven gyro and synchronized with, or slaved to, the earth's magnetic field. The indicator, mounted on the instrument panel, consists of a heading dial, synchronizing knob, and an annunciator window (fig. 2-21). The rotatable heading dial is calibrated in 5° increments. The 30° points are numbered, and the cardinal points are shown by letters. Reciprocal headings can be read from the small window in the lower face of the instrument. For operation, see paragraph 2-25.

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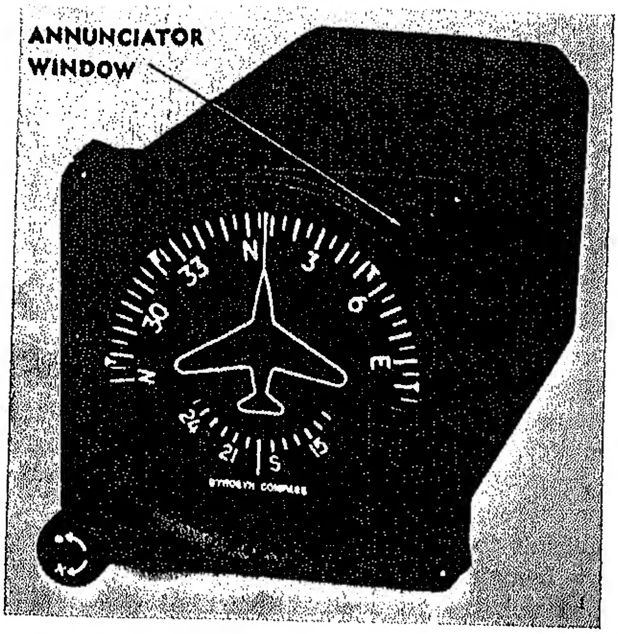

Figure 2-21. Heading indicator ID-567 /ASN.

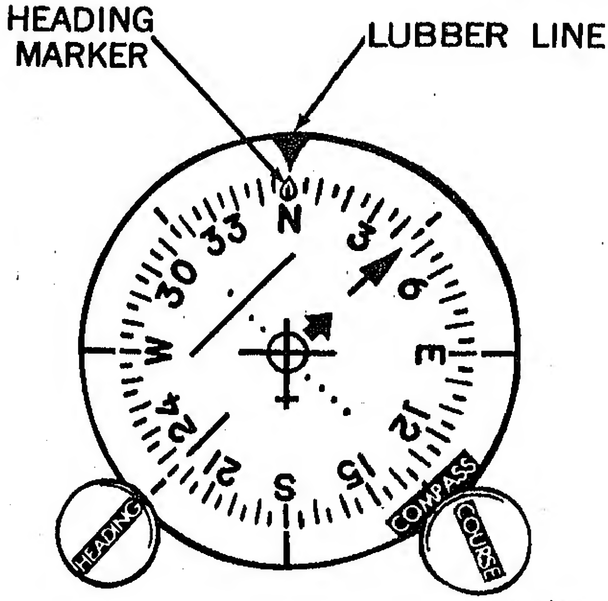

Figure 2-22. Course indicator ID-883.

2-27. Radio Magnetic Indicator (RMI) ID-998/ASN

The radio magnetic indicator ID-998/ASN (fig. 2-19) is normally the primary heading indicator. It represents aircraft headings by a rotating compass card. For compass operation, see paragraph 2-25. A single-bar and a double-bar needle present radio bearing information from ADF and/or VOR receivers. For in-flight use of the radio bearing needles, see TM 1-225.

2-28. Radio Magnetic Indicator (RMI) ID-250/ARN

The radio magnet indicator ID-250/ARN (fig. 2-19) is similar to the ID-998/ASN, but is normally used as a repeater indicator for the copilot installation.

2-29. Course Indicator ID-883

The ID-883 course indicator (fig. 2-22) includes an azimuth ring and lubber line. The azimuth ring is driven by the aircraft compass system and rotates as the aircraft heading changes. The aircraft heading is indicated by the position of the azimuth ring with respect to the lubber line. The left knob controls the heading marker. This instrument activates the steering pointer of the ID-882 navigation attitude indicator (fig. 2-16). The COMPASS warning flag appears when the magnetic compass indicator circuits are not operating properly. Components other than the azimuth ring are indicators for radio receivers. For in-flight operation, see TM 1-225.

Section IX. THE PITOT-STATIC SYSTEM

2-30. General

The pitot-static system (fig. 2-23) is the source of power for the operation of the differential pressure instruments—the altimeter, vertical speed indicator, instantaneous vertical speed indicator (IVSI), and the airspeed indicator. The differential pressure used to power these instruments is created either by impact and static or by static and trapped air pressures. The pitot-static system supplies both impact and static pressures through connecting lines to the instruments. The indications on the calibrated scales of these instruments result from differences in air pressures that exist within each of the instruments. To interpret the indications of these instruments

properly, it is essential for the aviator to understand the construction, operation, and use of the entire pitot-static system.

2-31. Impact Pressure

Impact pressure is required for the operation of the airspeed indicator. The open pitot tube is mounted on the aircraft, parallel to the longitudinal axis of the aircraft, where there is a minimum disturbance of air caused by aircraft motion. Two major parts make up the pitot tube—the impact pressure chamber with lines and the heating unit. The pitot tube receives the impact pressure of the air. This impact pressure increases with the speed of the aircraft. Since the diaphragm (fig. 2-31) of the airspeed indicator is connected directly to the pitot line, it is expanded by this increase in impact pressure. The expansion or contraction of the diaphragm, in turn, controls the position of the airspeed needle by a series of levers and gears.

2-32. Static Pressure

To obtain the required difference in pressure for the operation of the differential pressure instruments, static air pressure from the atmosphere is supplied to the instruments through static vents (fig. 2-23). The vents are installed at a point where the low pressure effect from the surrounding flow of air is at a minimum. These vents are interconnected to a common line to the instruments by a Y-fitting. By placing and connecting the vents in this manner, there is a minimum error in static pressure due to erratic changes in the attitude of the aircraft. During preflight inspection, the aviator must check the flush-type vents visually to see that they are not clogged.

a. Alternate Source of Static Pressure. In aircraft using the flush-type static pressure source, an alternate source for static pressure is not readily available. To obtain an alternate source, the glass in one of the three static pressure instruments must be broken. It is difficult to break the glass without damaging the instrument; for this reason, it is advisable to break the glass on the vertical speed indicator since this is the least important instrument during an instrument letdown and/or landing.

b. Instrument Reading Under Broken Glass Conditions. If the glass of the vertical speed indicator is broken and the instrument is still operating, its normal indications will be in reverse; those of the altimeter and the airspeed indicator will lag because the static pressure now comes from the cockpit and forces its way to the other instruments through the calibrated leak in the vertical speed indicator.

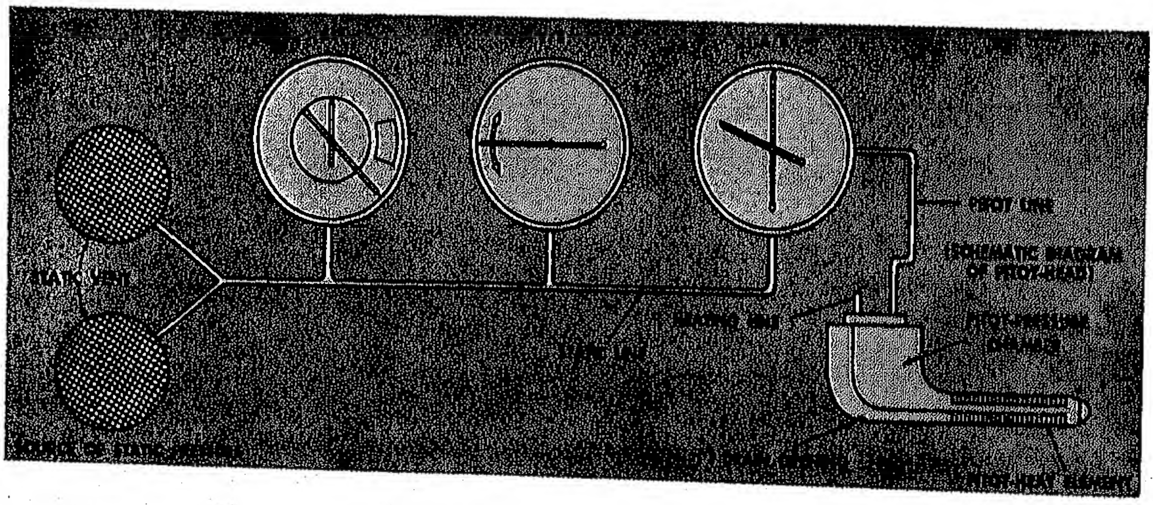

Figure 2-23. Flush type pitot-static system.

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Section X. THE PRESSURE ALTIMETER

2–33. General

The atmosphere surrounding the earth exerts downward pressure because of its weight. The air near the earth is weighted down and compressed by the air above and thus has greater density than the air above. This difference in pressure at various levels is utilized by the altimeter. The [illegible]ure *altimeter* (fig. 2–24) is essentially a [illegible]ure measuring device calibrated to con[illegible] atmospheric pressure to an altitude indication. The conversion is based on a fixed set of values known as the U.S. Standard of Atmosphere. A portion of these values is tabulated in table I. Although these atmospheric values exist only on paper, they were constructed by a formula which approximates the average pressure and temperature of 45° north latitude in the United States. Up to an altitude of about 15,000 feet, pressure decreases approximately 1 inch Hg per 1,000 feet. A pressure setting knob (fig. 2–24) compensates for nonstandard conditions of surface pressure that exist from day to day (para. 2–36*b*).

Table I. Standard Pressure and Temperatures at 1,000-Foot Intervals

Feet	Pressure (Inches Hg)	Degrees Temperature (C.)
16,000	16.21	-17
15,000	16.88	-15
14,000	17.57	-13
13,000	18.29	-11
12,000	19.03	-9
11,000	19.79	-7
10,000	20.58	-5
9,000	21.38	-3
8,000	22.22	-1
7,000	23.09	1
6,000	23.98	3
5,000	24.98	5
4,000	25.84	7
3,000	26.81	9
2,000	27.82	11
1,000	28.86	13
Sea Level	29.92	15

2–34. Construction of Altimeter

The basic component of the pressure altimeter is a series of aneroid wafers (fig. 2–25). The aneroid wafers are airtight cells from which nearly all of the air has been evacuated. This series of interconnected wafers contracts or expands with changes of atmospheric pressure. As the aircraft altitude increases, the static pressure surrounding the

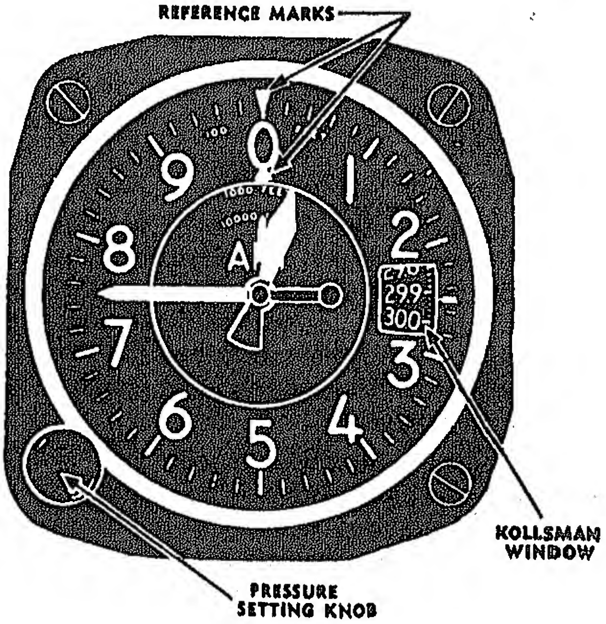

Figure 2–24. The pressure altimeter.

Figure 2–25. Cutaway view of the altimeter.

wafers decreases and allows the wafers to expand. When the aircraft altitude decreases, the static pressure surrounding the wafers increases, causing the wafers to contract. One end of the stack of wafers is attached to the instrument case and the other is linked by a lever to a shaft. A linkage and gear assembly is also connected to the shaft. Expansion or contraction of the wafers causes the shaft to rotate. This rotation through the gearing mechanism positions the hands on the altimeter dial to indicate the altitude.

2-35. Reading the Altimeter

The altimeter dial (fig. 2-24) is properly read by noting the position of all three hands in order, from the shortest to the longest. The shortest hand indicates tens of thousands; the intermediate hand, thousands; and the longest hand, hundreds. The indication in figure 2-24 illustrates 750 feet.

a. The old type altimeter dial (fig. 2-24) has been modified because of difficulty in rapidly determining thousands and tens of thousands of feet. The MB-2 (fig. 2-26) was developed both as a new altimeter and as a conversion of older models. It has a cross-hatched "flag" on the lower part of the dial and, instead of a 10,000-foot needle, it has a disk with a pointer extending out to the edge of the dial. A hole in the disk is located so that the edge of the flag barely shows at about 15,000 feet; at altitudes below 10,000 feet, the whole flag shows.

b. A barometric scale is visible through an opening (Kollsman window) in the right-hand side of the altimeter dial. This scale is calibrated from 28.10 to 31.00 inches Hg, and is rotated by the setting knob. Rotating the setting knob provides altimeter adjustment to nonstandard conditions of pressure (other than those in table I). For example, assume that an altimeter is placed on the beach and set at 29.92 inches Hg. If the hands indicate an altitude of 200 feet, the barometric pressure at that point on the beach is lower than standard. A barometric pressure of 29.72 inches Hg will cause a 200-foot-high indication if 29.92 inches Hg is set into the Kollsman window; if 29.72 inches Hg is rotated into the Kollsman window, the hands will return to zero. (One inch Hg equals 1,000 feet; 0.20 inches Hg equals 200 feet.) In effect, the hands have been assigned a different pressure for their zero indication. Rotating the setting knob on the altimeter merely displaces the hands a given amount with respect to the aneroid wafers.

2-36. Effect of Nonstandard Temperatures and Pressures

Atmospheric temperature and pressure vary continuously. Rarely is the pressure at sea level exactly 29.92 inches Hg or the temperature +15° C. Furthermore, the temperature and the pressure may not decrease with altitude increase at a standard rate. Even if the altimeter is properly set for surface conditions, it will often be incorrect at higher levels. On a warm day the air expands and weighs less per unit volume than on a colder day, and the pressure levels are raised. On a cold day, the reverse would be true.

a. Altimeter Error Due to Nonstandard Temperature. If the air is warmer than the standard temperature for flight altitude, the aircraft will be higher than the altimeter in-

Figure 2-26. The MB-2 altimeter dial.

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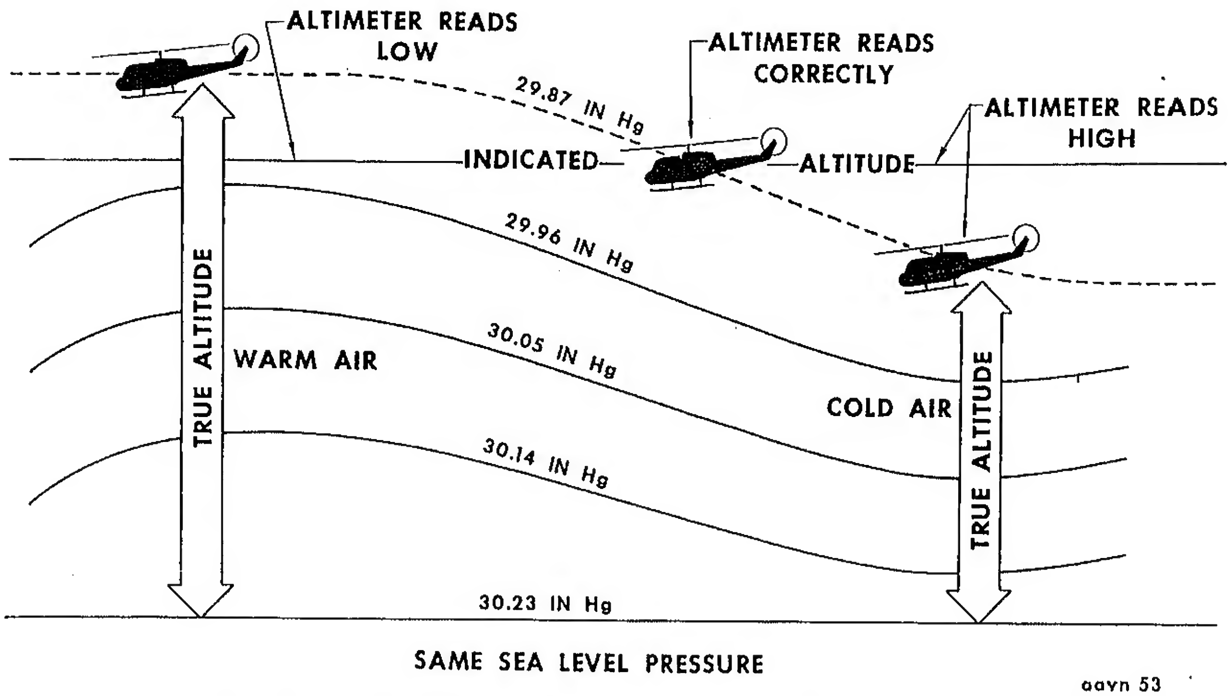
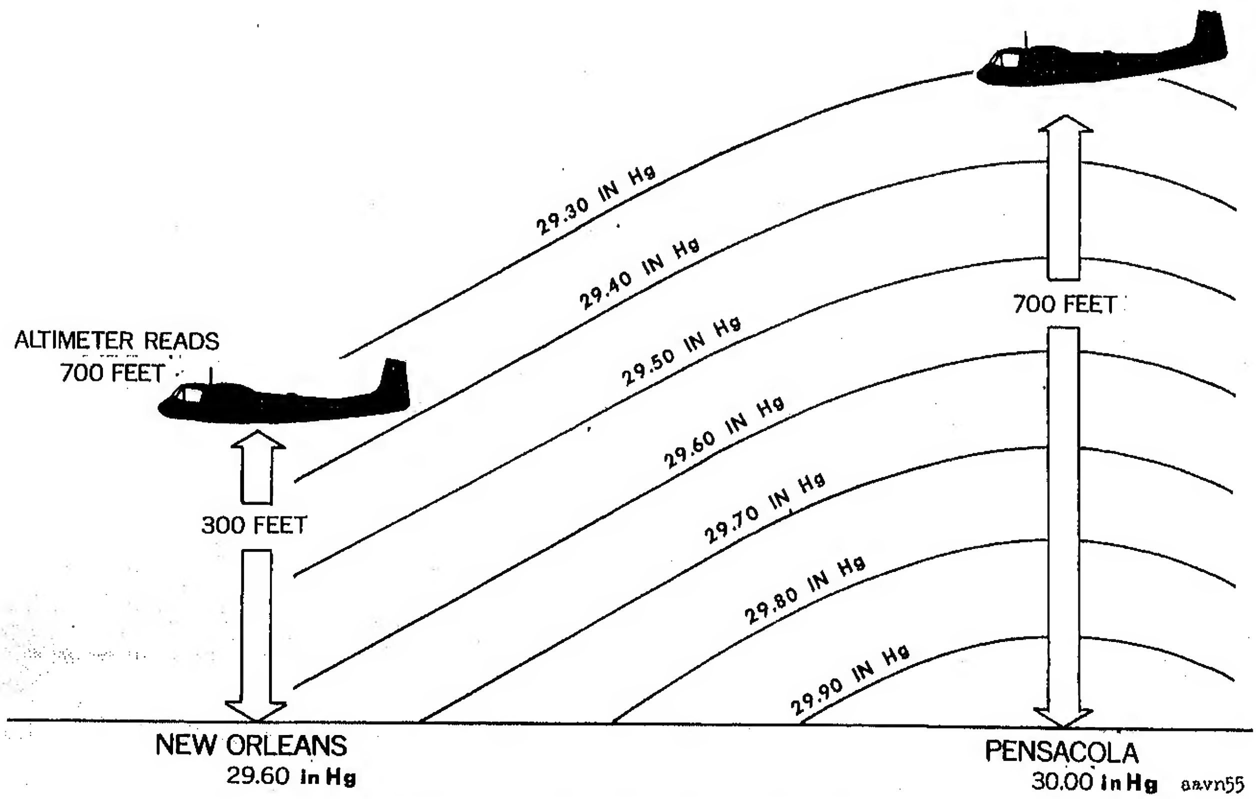


★*Figure 2-27. (Superseded) Altimeter errors due to nonstandard temperatures.*



★*Figure 2-28. (Superseded) Altimeter error due to nonstandard atmospheric pressure.*

dicates; if the air is colder than standard temperature for flight altitude, the aircraft will be lower than the altimeter indicates (fig. 2-27).

b. Altimeter Error Due to Nonstandard Atmospheric Pressure. Figure 2-28 shows the error in altimeter reading that would result if the aviator failed to adjust the altimeter for variations from standard atmospheric pressure. The figure shows a pattern of isobars in a cross section of the atmosphere from Pensacola, Fla. to New Orleans, La. The pressure at Pensacola is 30.00 inches Hg and the pressure at New Orleans is 29.60 inches Hg, a difference of 0.40 inches Hg. Assuming that the aircraft takes off from Pensacola to fly to New Orleans at an altitude of 700 feet, a decrease in mean sea level (MSL) pressure of 0.40 inches Hg from Pensacola to New Orleans could cause the aircraft to gradually lose altitude and, although the altimeter would continue to indicate 700 feet, the aircraft could actually be flying at approximately 300 feet over New Orleans.

2-37. Setting the Altimeter

★*a. Current Altimeter Setting.* The current altimeter setting is normally given to the aviator during radio communications with the control tower, FAA flight service stations, and other air traffic control personnel. However, the altimeter setting may be requested at any time. The first altimeter setting is normally made while on the ground. This gives the aviator an opportunity to check the accuracy of the altimeter. To do this, he sets the report altimeter setting on the barometric scale and compares the indicated altitude to a known elevation. The maximum allowable error is 70 feet. If the altimeter error exceeds 70 feet, the altimeter is not considered reliable. No further corrections are necessary if the altimeter is within tolerance. Additional altimeter settings used should be the current reported altimeter setting of stations along the route within 100 nautical miles of the aircraft. If there is no station within 100 nautical miles, the current reported altimeter setting of the nearest available station should be used.

b. Altimeter Setting System. The altimeter setting broadcast by control towers and radio stations is a correction for *nonstandard surface pressure only.* Atmospheric pressure is measured at each station and the value obtained is corrected to sea level according to the station's surveyed elevation. Thus, the altimeter setting is a computed sea level pressure and should be considered valid only in close proximity to the station and near the surface. Nonstandard lapse rate errors may exist at all altitudes. However, at low altitudes the error is usually small.

(1) The obstruction clearance limits published for airways and instrument approaches will normally provide the necessary margin of safety for aircraft operating under instrument flight rules. Altitude separation between aircraft is maintained as long as the current altimeter setting is used. For example, in figure 2-29 aircraft "A" is assigned 5,000 feet eastbound and, with the current altimeter setting applied, indicated altitude is 5,000 feet. However, due to nonstandard conditions aloft, actual altitude is only 4,700 feet. Aircraft "B" is assigned 6,000 feet westbound and, with the current altimeter setting applied, the indicated altitude is 6,000 feet. The same nonstandard conditions affect aircraft "B" and the actual altitude is 5,700 feet. Even though both aircraft are 300 feet below indicated altitude, they will still retain 1,000 feet vertical clearance as they approach and pass each other.

(2) At higher altitudes, pressure and temperature deviation from standard

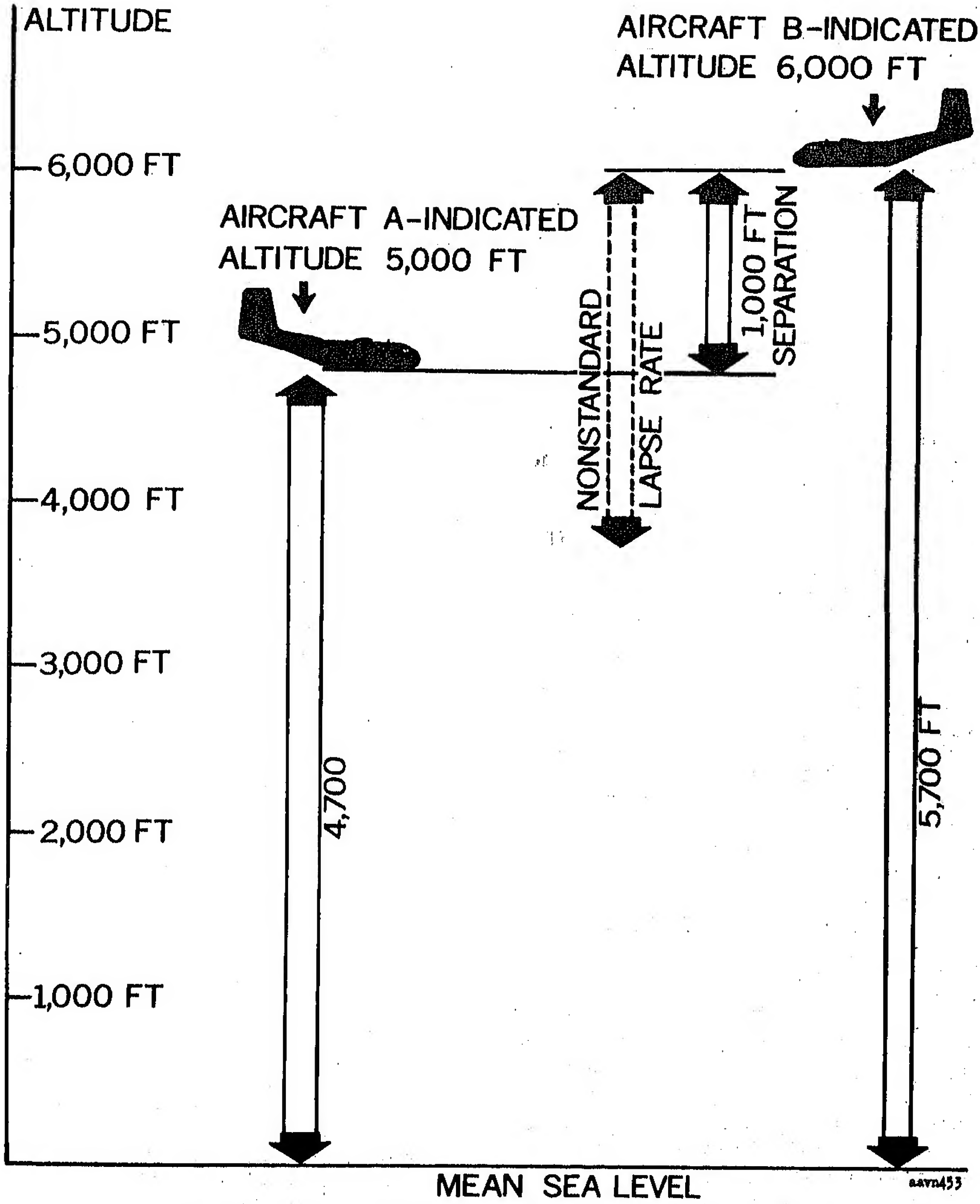


Figure 2-29. Maintaining altitude separation by using current altimeter setting.

conditions could combine to cause altimeter errors that would place the aircraft below a safe terrain clearance altitude. A *high altimeter setting* combined with a pressure level aloft which is lower than standard is particularly dangerous in mountainous terrain. For this reason, the aviator should always consult the weather forecaster to analyze pressure patterns at high altitudes. For a complete discussion of this type altimeter error, see paragraph 14.10 of TM 1-300.

2-38. Types of Altitude

Types of altitude most often used are—

a. Indicated Altitude. Indicated altitude is altitude as read on the dial with a current altimeter setting (sea level pressure) set into the Kollsman window (para. 2-37*a* above).

b. Pressure Altitude. Pressure altitude (fig. 2-30) is the height measured above the 29.92 inches Hg pressure level (*standard datum plane*). If the Kollsman window is set to 29.92 inches Hg, the hands of the dial indicate pressure altitude. The use of pressure altitude begins at 24,000 feet in the United States. Pressure altitudes are referred to as *flight levels* (FL). *For example,* 24,000 feet = FL-240; 35,000 feet = FL-350.

c. Absolute Altitude. Absolute altitude (fig. 2-30) is the height or altitude above the surface or terrain over which the aircraft is flying.

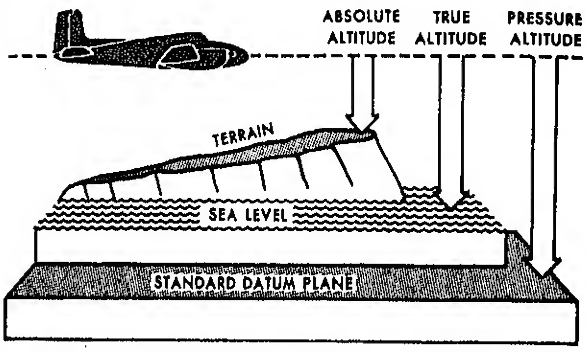


Figure 2-30. Types of altitude.

d. True Altitude. True altitude (fig. 2-30) is the altitude above mean sea level. Full discussion is found in TM 1-300; for calculation of true altitude, refer to TM 1-225.

e. Density Altitude. Density altitude is the altitude for which a given air density exists in the standard atmosphere. If the barometric pressure is lower or the temperature is higher than standard, then density altitude of the field is higher than its actual elevation. *For example,* for Denver, Colorado, with an elevation of 5,500 feet, a temperature of 110° F., and barometer reading (corrected to MSL) of 29.55 inches Hg, density altitude is about 10,000 feet. Since higher density altitude requires a greater takeoff distance and reduces aircraft performance, failure to calculate density altitude in some situations could have fatal results. Density altitudes can be obtained from many airfield towers or may be computed on the dead reckoning computer (TM 1-225).

Section XI. THE AIRSPEED INDICATOR

2-39. Construction

The airspeed indicator has a cylindrical airtight case connected to the static line. Inside the case is a small diaphragm made of phosphor bronze or beryllium copper. The diaphragm, which is very sensitive to changes in pressure, is connected firmly at one side to the impact pressure line. The needle is connected through a series of levers and gears to the free side of the diaphragm (fig. 2-31).

2-40. Operation

The airspeed indicator is a differential pressure instrument. It measures the difference between the pressure in the impact pressure line and the pressure in the static pressure line. The two pressures are equal when the aircraft is stationary on the ground, but movement through the air causes the pressure in the impact line to become greater than the pressure in the static line. The diaphragm, being connected directly to the impact pressure

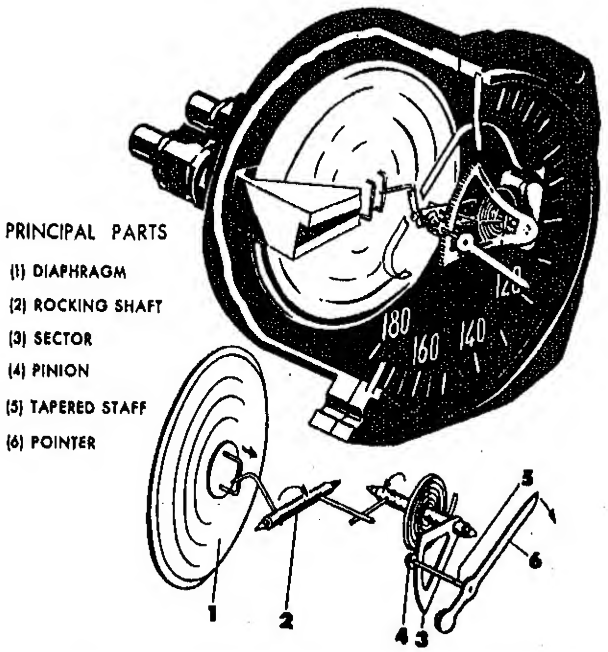


Figure 2-31. Cutaway view of the airspeed indicator with component parts.

line, will expand due to increased impact pressure. The dial is scaled so that the needle will indicate this pressure differential in knots.

2-41 Kinds of Airspeeds

There are three kinds of airspeeds—*indicated, calibrated,* and *true.*

a. Indicated Airspeed. Indicated airspeed is the airspeed read directly from the indicator.

b. Calibrated Airspeed. Calibrated airspeed is indicated airspeed corrected for instrument installation error. This error is caused by the difference in the static pressure at the pitot head and the static pressure at the static vents. The error is usually small and may be computed by reference to the appropriate aircraft operator's manual.

c. True Airspeed. True airspeed is airspeed corrected for error due to air density (altitude and temperature). —This may be solved on the dead reckoning computer (TM 1-225).

Section XII. THE VERTICAL SPEED INDICATOR

2-42. Construction

The vertical speed indicator (A, fig. 2-32) has a sealed case connected to the static pressure line through a calibrated leak. Inside the case is a diaphragm similar to that in the airspeed indicator (para. 2-39). This diaphragm is connected directly to the static pressure line. A system of levers and gears connects the diaphragm to the indicating needle on the face of the instrument (B, fig. 2-32). The vertical speed indicator contains a mechanism which enables it to compensate automatically for changes in air temperature.

2-43. Operation

Although the vertical speed indicator operates entirely from static pressure, it is a differential pressure instrument. The differential pressure is established between the instantaneous static pressure in the diaphragm and the trapped static pressure within the case. When the aircraft starts a climb, the pressure in the diaphragm decreases in ratio to the reduction in atmospheric pressure. The calibrated leak retards the pressure change to the instrument case. This causes the diaphragm to contract, causing the needle to indicate an ascent. The leak in the case is calibrated so that it maintains a definite ratio between the pressure in the diaphragm and the pressure in the case as long as a constant rate of climb is maintained. When the aircraft levels off, the calibrated leak requires 6 to 9 seconds to equalize the two pressures. This causes a lag of 6 to 9 seconds in the instrument. When the aircraft is descending, the pressure inside the diaphragm is increasing and the calibrated leak again maintains a constant relation between the two pressures.

2-44. Instrument Lag

The vertical speed indicator gives the rate at which the aircraft is climbing or descending (or indicates level flight). These indications are not reliable in extremely rough air or when the attitude of the aircraft is constantly changing. This is due, in part, to the lag in the instrument. The instrument can be used

A Indicator face

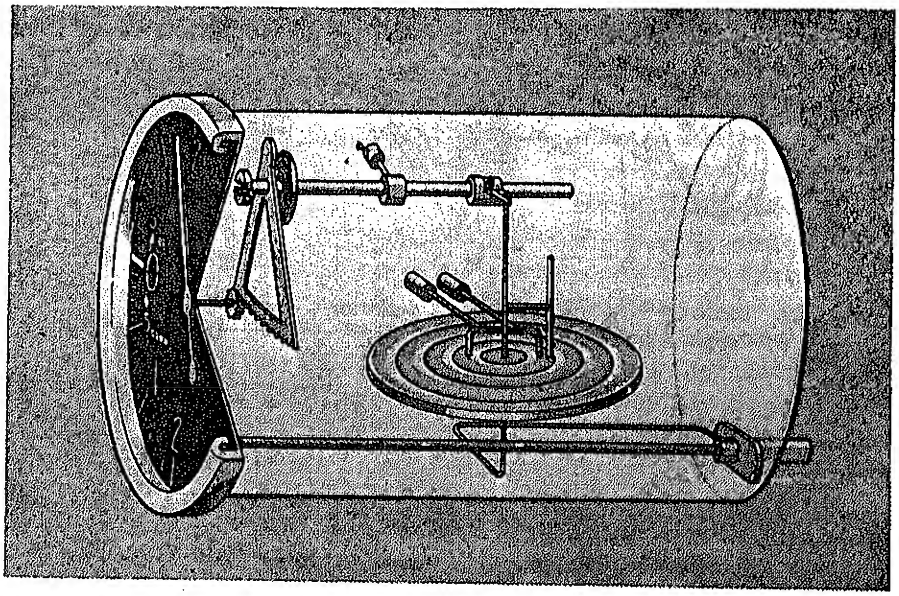


Figure 2-32. The vertical speed indicator.

for indications of pitch attitude if a thorough understanding of its lag is considered in interpreting the indications.

2-45. Adjustment

The needle of the vertical speed indicator should indicate zero while the aircraft is on the ground or maintaining a constant altitude; any reading other than zero indicates a need for adjustment. This adjustment can be made by using a small screwdriver to turn the screw in the lower left corner of the instrument.

2-46. Instaneous Vertical Speed Indicator (IVSI)

The instantaneous vertical speed indicator can be identified by the letters IVSI that appear on the dial. Compared to conventional vertical speed indicators, this instrument has no apparent lag. The instantaneous vertical speed indicator is similar in construction to conventional vertical speed indicators (para. 2-42 above); it differs from these indicators by the addition of two accelerometers which generate pressure differences whenever there is a change in the normal acceleration of the aircraft. The pressure differences are transmitted to the sensitive diaphragm by pneumatic circuits. A velocity is added, as necessary, to the pressure-leak velocity to obtain the total, nearly instantaneous vertical speed indication. As the pressure-leak component approaches the actual speed, the integrated component fades out.

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a. The sum of the pressure-leak and accelerometer velocities is the total vertical airspeed, provided the normal axis of the aircraft is within about 30° of the vertical.

b. Since the accelerometers are not vertically stabilized, some error is generated in turns. If a zero indication is maintained on the instantaneous vertical speed indicator when entering a turn, some loss in altitude will be encountered. A corresponding gain in altitude will result when recovering from a turn. The instantaneous vertical speed indicator should not be used for directly controlling vertical speed when rapidly banking in excess of 40°. However, the indicator is not affected once in a steady turn.

c. The fade-out of acceleration in a steady turn occurs because when a turn has been started and the accompanying change in normal acceleration has been completed, the accelerometer masses will settle to new balance points corresponding to the normal acceleration maintained in the turn. In establishing a 30° bank, altitude deviation should not exceed 90 feet while maintaining the instantaneous vertical speed indicator at 0. In more steeply banked turns, the turn error rapidly increases with bank angle. Thus, the use of the instantaneous vertical speed indicator should be limited to the maneuvers of normal instrument flying.

CHAPTER 3

SENSATIONS OF INSTRUMENT FLIGHT

Section I. DISORIENTATION AND THE ILLUSIONS OF FLIGHT

3-1. Sensory Illusions

A sensory illusion is a false interpretation of sensations transmitted from the *eyes*, the *vestibular apparatus*, and the *postural senses*. Sensory illusions have been a problem since man's first attempt to fly. The aviator must learn to ignore confusing sensory information and rely only on the objective evidence provided by the aircraft's instrumentation.

a. Spatial Disorientation. Spatial disorientation is an inability to orient oneself properly with respect to the earth's surface; it is a part of certain sensory illusions.

b. Vertigo. Vertigo is the aviator's illusion of the sensation of rotation (dizziness occurring during flight). Many aviators erroneously refer to all sensory illusions, with or without the sensation of rotation, as vertigo.

3-2. Vision

a. General. Man, by experience, has learned the meaning of the horizon and instinctively corrects for changes in the horizontal. The presence of a stable horizon makes it possible for most individuals to remain oriented. However, severe stimulation to any one of the organs of equilibrium may produce significant disorientation effects.

b. Visual Illusions.

(1) *Autokinetic illusion.* Because the eyes are unable to remain fixed on a single light viewed against a dark background, the light appears to move. This illusion can be eliminated by visual scanning, by increasing the number of lights, or by varying the light intensities. This illusion has occurred quite frequently during night formation flights when a wingman continues to stare at the wingtip light of the lead aircraft.

(2) *Relative motion.* The motion of a wingman can be interpreted as motion of the flight leader. Such transposition is frequently seen in a railroad station where the motion of a nearby moving train is misinterpreted as being the motion of a stationary train.

(3) *False horizons.* In the absence of a terrestrial horizon, a slanting cloud bank may be misinterpreted as being horizontal.

(4) *Altered plans of reference.* When approaching a line of mountains or clouds, there is a tendency to climb. The reverse is true when leaving such a line. In flying parallel to a line of clouds, there is a tendency to tilt away.

(5) *Confusing lights.* Ground lights can easily be misinterpreted as stars.

(6) *Depth perception.* Inadequate visual references, while flying at night or over water, result in diminished depth perception and dangerous illusions may occur.

(7) *Flicker vertigo.* Lights flickering at a rate of 4 to 20 cycles per second can produce unpleasant and dangerous reactions including nausea, vertigo, convulsions, and unconscious-

ness. Fatigue or frustration tend to strengthen these reactions. The majority of evidence indicates that these hazards are not a serious problem in Army aviation. However, the problem is a potential one that every aviator should be aware of. Research indicates that flicker vertigo can be caused by—

(*a*) The passage of sunlight through propeller blades.

(*b*) Rotor blades.

(*c*) Dual rotating beacons flickering against an overcast sky.

3-3. The Vestibular Apparatus

a. General. The inner ear is imbedded in the temporal bone of each side of the head and contains both the organ of hearing and the vestibular apparatus of equilibrium. The vestibular apparatus is made up of three semicircular canals. When the head is upright, these canals lie at right angles to each other in three planes (horizontal, vertical, and transverse). Their general structure can be seen in figure 3-1. Hairlike filaments in the canals (A, fig. 3-1) sense the motions of the fluid about them and signal the brain according to the motions sensed.

(1) If the position of the head is abruptly changed, the fluid in the canals lags because of inertia. The hairlike nerve ends then displace in the opposite direction and relay this message to the brain (B, fig. 3-1).

(2) Minimum accelerations (vestibular threshold) of motion are required before the vestibular apparatus will transmit any signals at all. The following minimum accelerations are averages:

(*a*) Linear: 4.5 inches per second per second.*

(*b*) Angular: 3.0 inches per second per second.

(*c*) Radial: 2° per second per second.

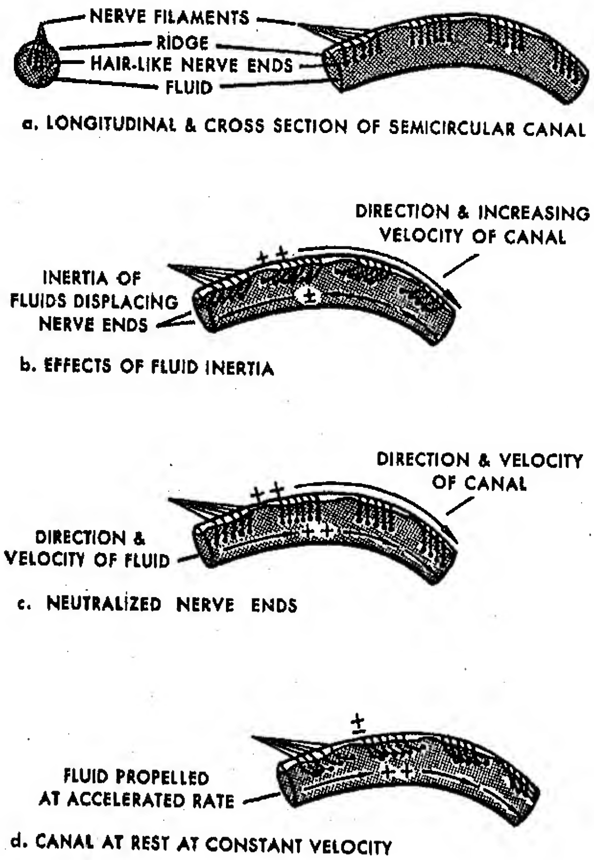

Figure 3-1. Vestibular system effects.

(3) Once the inertia of the fluid is overcome by acceleration and the nerve ends are neutralized (C, fig. 3-1), the signal thus generated is likewise transmitted to the coordination centers of the brain.

(4) Under the conditions described above, in-flight errors of the vestibular apparatus are understandable. If acceleration stops and the semicircular canals reach a constant velocity or come to rest (D, fig. 3-1), the fluid continues to move as before and temporarily at the accelerated rate. The nerve filaments signal the brain of movement in a direction opposite that just traveled. This is the most

* The term "per second per second" means that the rate of acceleration changes so much per second every second; e.g., 2, 4, 6, 8, 10, etc., with each succeeding second.

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serious shortcoming of the vestibular apparatus and leads to several sensory illusions in flight.

b. Vestibular Illusions. Illusions caused by limitations of the vestibular apparatus are—

(1) *Leaning.* The aircraft may be tipped quickly by rough air and the aviator gets correct sensations of the attitude of the aircraft. Then, the aviator may recover the aircraft by an imperceptibly slow return to straight and level flight. The aviator retains the feeling he is "leaning" even though he is in a level attitude. Angular motion is not perceived at a rate below the threshold of vestibular stimulation (para. 3–3*a*(2)(*b*).

(2) *Tilting.* A sensation of opposite tilt in a skid may occur in an uncoordinated turn. With insufficient bank, the hair cells of the semicircular canals are bent away from the turn and a sensation of a tilt away from the direction of the turn is produced. The illusion occurs most frequently in turbulent air, particularly under instrument flight conditions. Since the aviator does not correct rolling and pitching of the aircraft constantly, a low wing, for example, may rise to normal attitude without the minimum vestibular acceleration required (2° per second per second) for nerve sensation. Then, although his instruments indicate a return to even keel, the aviator's compulsion is very strong to tilt against the former tilt of the wing.

(3) *Pitching.* Sensations of climbing while in a turn, diving when leveling off from a climb, or climbing after leveling off from a dive are related primarily to postural sensations and changes in apparent weight. However, vestibular stimulation similar to that producing leans complicates the sensation of pitching.

(4) *Spinning.* If the rate of rotation is held reasonably constant for 20 seconds or more, fluid flow within the semicircular canals ceases and the hair cells tend to return to a normal position. When the rotation or spin stops, the fluid within the semicircular canals again produces a relative flow by inertia and a sensation of turning or spinning in a direction opposite to the original occurs. Thus, the aviator pulling his aircraft out of a spin experiences a sensation of spinning in the opposite direction. If he commits the error of correcting for this false sensation, he goes back into the original spin.

(5) *Sensations from centrifugal force.* When an aviator moves his head up or down while in a turn or a spin, a second set of canals is stimulated and a violent sensation of tumbling occurs that may be accompanied by true vertigo and even nausea on occasion.

(6) *Oculo-gyral illusion.* If visual clues are reduced, vestibular stimulation may cause strong visual illusions of apparent motion that persist after the actual rotation has stopped.

(7) *Oculo-gravic illusion.* During accelerative maneuvers, stimulation of the semicircular canals may interact with eye movements to cause an apparent change in the position of objects within the visual field.

3–4. The Postural Senses

a. General. With training and experience, the aviator can distinguish the more distinct movements of the aircraft by the pressures of the aircraft seat upon his body while seated in flight. This is known as the "seat-of-the-britches" sensation. This includes sensations resulting from pressures on joints, muscles, skin, and also those from slight changes in position of internal organs. This sensation is intimately associated with the vestibular apparatus and to a lesser degree with the visual sense. The aviator mobilizes and uses all of these resources when he adapts himself and gets the "feel of the aircraft."

b. Postural Illusions.

(1) *Pitch.* A properly executed turn vectors gravity and centrifugal force through the vertical axis of the aircraft. In the absence of visual references, the only sensation is body awareness of being pressed more firmly into the seat. This sensation is normally associated with climbing and may be thus falsely interpreted by the aviator. Recovery from turning lightens pressure on the seat and this creates an illusion of descending.

(2) *Skid.* In a turn, skidding presses the body away from the direction of the turn. In blind flying this is interpreted by the senses as a tilt in the opposite direction. Likewise, slipping the aircraft in too steep a bank presses the body in the direction of the turn and may also create false illusions.

3–5. Limitations of Vestibular Apparatus and Postural Senses

When the eyes have enough information to go by, they provide reliable orientation information. However, in instrument flight, without vision it is necessary to depend entirely on instruments since the vestibular apparatus and postural senses often give misleading information. These senses act primarily on the basis of gravity and provide reliable orientation information while on the ground. When in flight, the aviator experiences acceleration and centrifugal forces that affect these senses exactly as gravity does, thus providing misleading information. For example, a banked turn may seem to be a straight and level flight since positive acceleration affects the vestibular apparatus and postural senses in the same manner as gravity.

Section II. OVERCOMING SENSORY ILLUSIONS

3–6. Safety Rules

The aviator should remember that *he is bound to experience sensory illusions* throughout his flying career. Since they cannot be avoided, a few safety rules should be practiced and, in time, a technique perfected for combating the ill effects of such illusions. A few rules to be practiced are—

a. Never fly without some VISUAL REFERENCE POINT.

b. Make full use of the horizon and/or attitude indicator.

c. Never stare at lights.

d. Delay intuitive action long enough to check your point of visual reference.

e. Carry a good flashlight to provide adequate illumination.

3–7. Intuition vs. Crosschecking

Crosschecking enables the aviator to repeatedly prove that his intuition is wrong. Thus he develops the habit of checking the instruments before changing the attitude of the aircraft. While crosschecking the instruments, rubbernecking, and using the systematic roving gaze to promote good night vision, the aviator learns and perfects a technique of combating the ill effects of the illusions. This technique should be fully established concurrently with other good habits in the development and maintenance of high instrument proficiency. As experience is gained in relying on instruments, distracting impressions of the mind become easier to overcome.

CHAPTER 4

POWER, PITCH, AND BANK CONTROL THROUGH INSTRUMENTS FOR FIXED AND ROTARY WING AIRCRAFT

Section I. GENERAL

4-1. Introduction

In instrument flying, attitude requirements are determined by interpretation of the instrument indications within the aircraft. The attitude of an aircraft is controlled by movement around its lateral, longitudinal, and vertical axes (figs. 4-1 and 4-2).

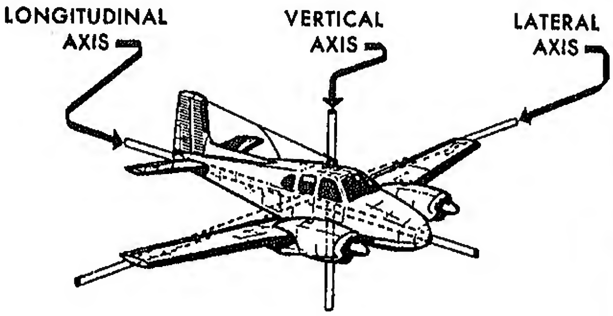

Figure 4-1. Axes of movement.

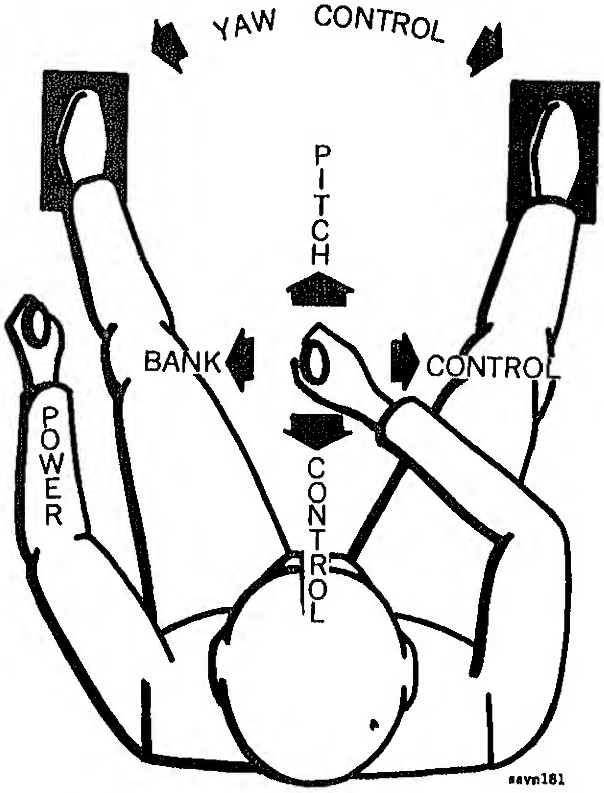

Figure 4-2. Power pitch, and bank control.

4-2. Cross-Checking

Observing and interpreting two or more instruments to determine the attitude and performance of an aircraft is called *cross-checking.*

a. Although no specific method of cross-checking is recommended, those instruments which give the best information for controlling the aircraft in any given maneuver should be used. The important instruments are the ones that give the most pertinent information for any particular phase of the maneuver, and are usually the instruments that should be held at a constant indication. The remaining instruments should be used to aid in maintaining the important instruments at the desired indications. This is also true in using emergency panel.

b. Cross-checking is mandatory in instrument flying. In visual flight, a level attitude can be maintained by outside references. However, even then the altimeter must be checked to determine if altitude is being maintained.

4-3. Trim

a. Proper trim technique is essential to smooth and accurate instrument flying. The aircraft should be properly trimmed while executing a maneuver. The degree of flying skill which an aviator will ultimately develop depends largely upon how well he learns to keep the aircraft trimmed.

b. An aircraft is rigged for flight at one particular airspeed and power setting (usually the normal cruising airspeed and power for the particular aircraft), and any deviation requires a change of trim. During transition from one flight attitude or power setting to another, the aircraft should be kept as nearly trimmed as possible by use of the trim controls. The basic problem in trimming is to determine when the proper amount has been applied. Every change of airspeed and/or power requires a readjustment of control pressures for balanced flight. Trim control can be used for relief of control pressures.

c. It is possible at times to hold pressures on the controls and be unaware of doing so. This can be overcome by relaxing pressure on the controls and, if necessary, adjusting trim.

Section II. POWER CONTROL

4-4. Power

Power produces thrust and gives motion to the wings (rotor(s)), thus creating lift. Sufficient power, combined with the appropriate attitude of the wing, overcomes the forces of gravity, drag, and inertia, and results in the desired performance of the aircraft.

4-5. Power Instruments

In all modern aircraft with constant speed propellers or rotor (rpm constant), the manifold pressure gage gives indications of the power output. The amount of power is indicated by the combination of tachometer and manifold pressure gage readings (fig. 4-3).

Note. In turbine power aircraft, the gage for measuring power is the torque meter, which gives the indicated power derived from the turbine engine.

4-6. Constant Airspeed

At a given flight airspeed the power setting determines whether the aircraft is in level flight, in a climb, or in a descent. If the altitude is held constant, the power determines the airspeed. At a constant altitude, cruising power results in cruising airspeed; therefore, cruising airspeed, if maintained with cruising power, results in level flight (A, fig. 4-4). If the power setting is increased and the airspeed held constant, the aircraft will climb (B, fig. 4-4). Conversely, if power is decreased and airspeed held constant, the aircraft will descend (C, fig. 4-4). Any deviation from the power setting results in a change in airspeed and/or the altitude of the aircraft.

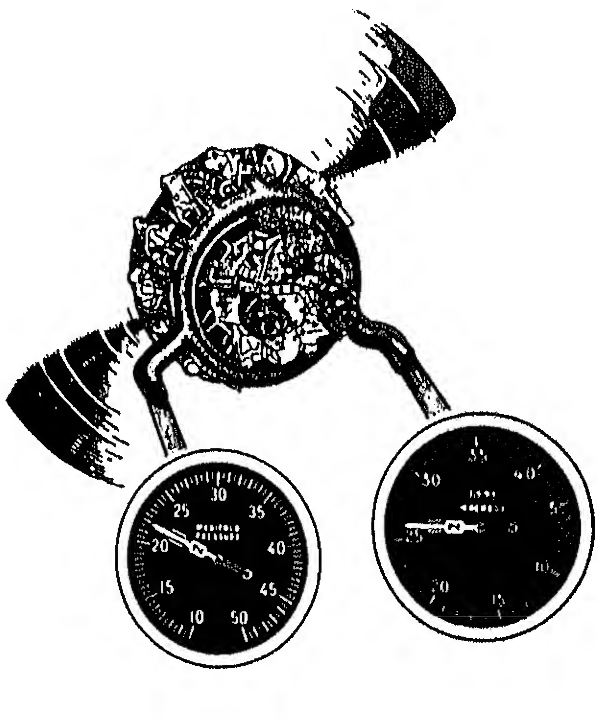

Figure 4-3. Power instruments.

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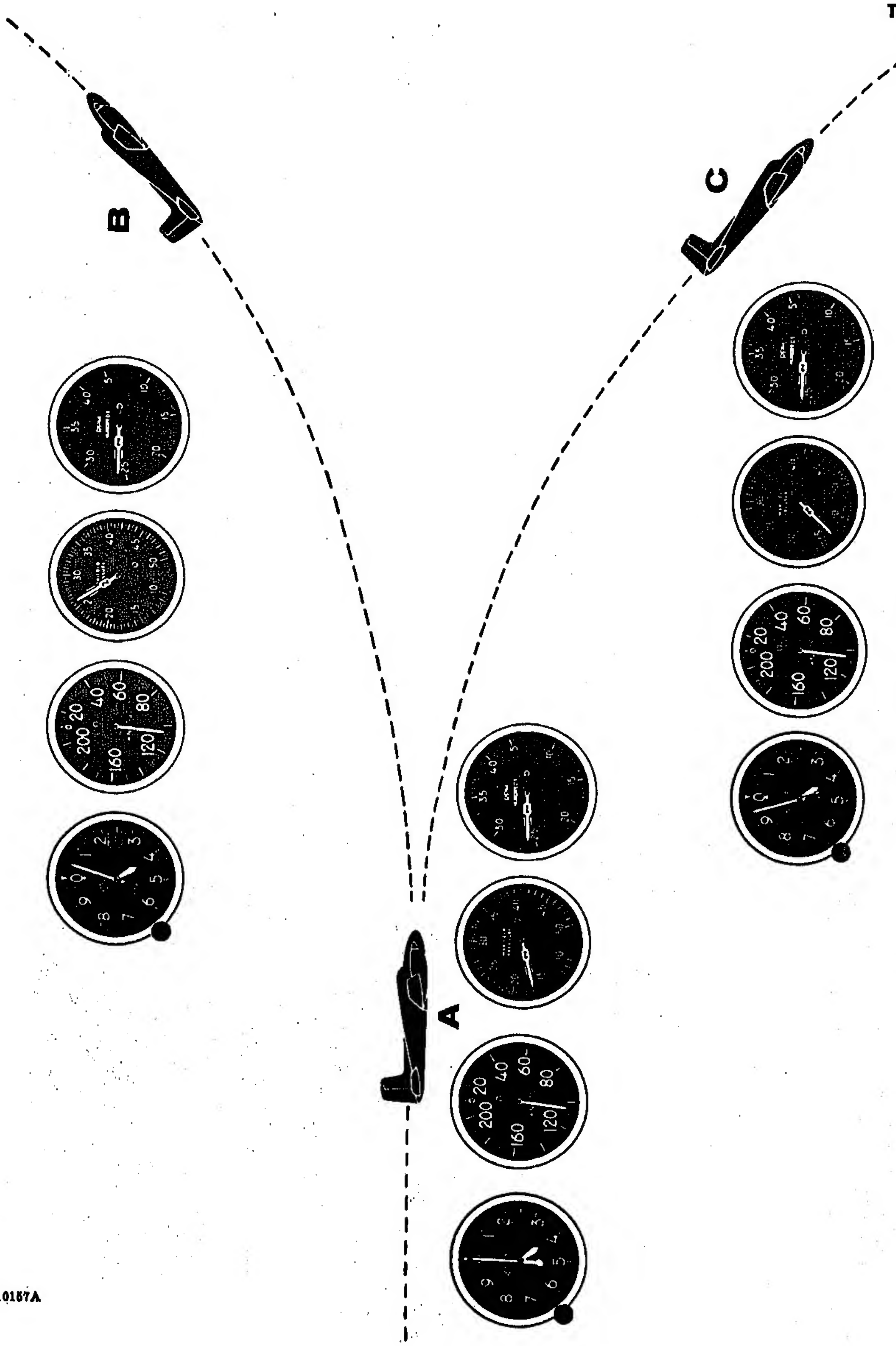

Figure 4-4. Effects of power changes while maintaining constant airspeed.

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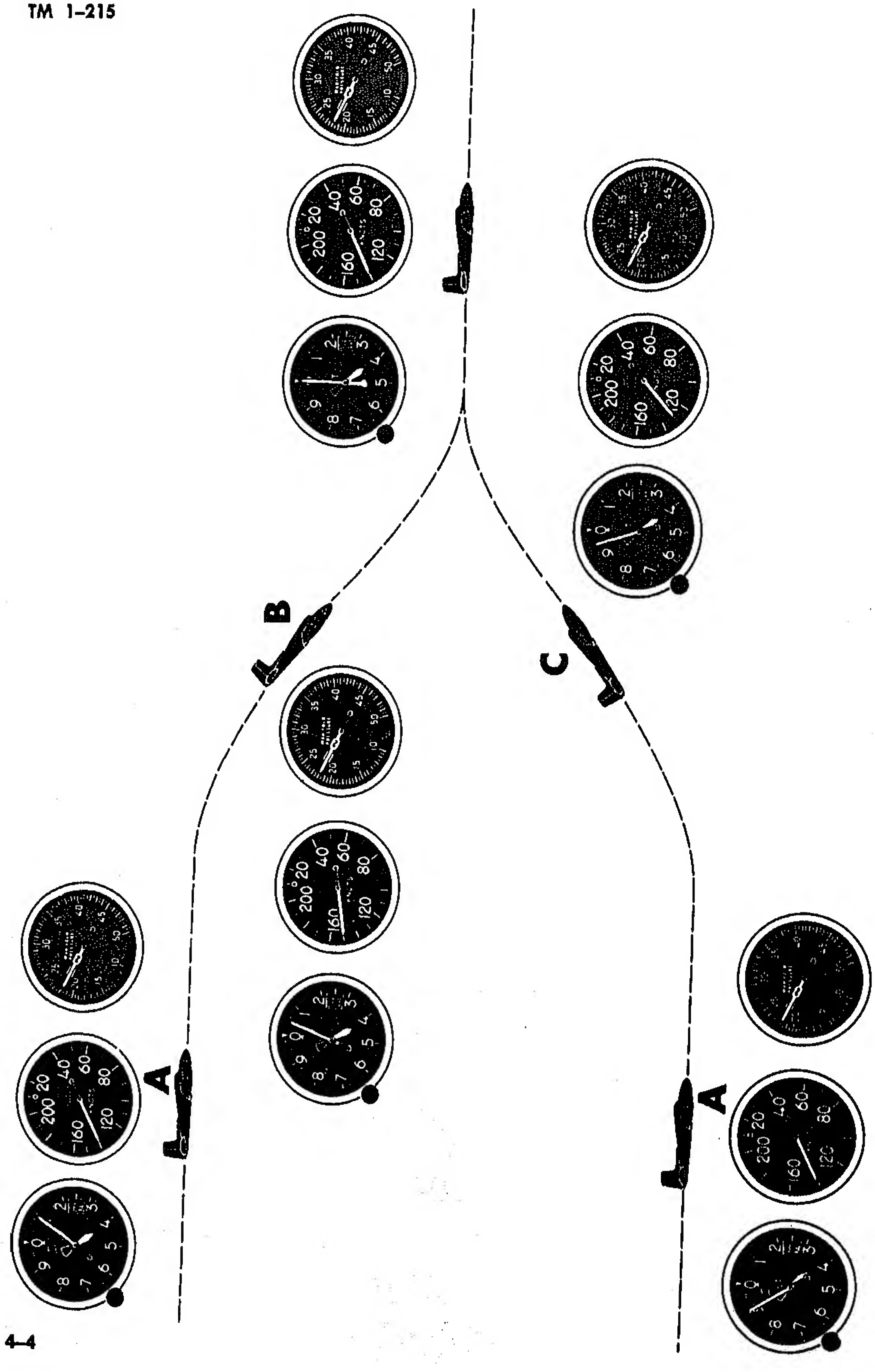

Figure 4-5. Airspeed converted to altitude and vice versa.

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4-7. Constant Altitude and Airspeed

Pitch and power control must be coordinated to maintain a constant altitude and airspeed in level flight (A, fig. 4-5). The relationship between altitude and airspeed determines the need for a change in pitch and/or power. If the altitude is constant and the airspeed is high or low, power must be changed to obtain the desired airspeed. Excess altitude or airspeed can be thought of as "stored" or reserve power. Minor changes in one may be made at the expense of the other without a change in power. *For example,* altitude can be converted into airspeed by diving (B, fig. 4-5) or conversely, airspeed can be converted into altitude by climbing (C, fig. 4-5). If, however, both altitude and airspeed are high, or if both are low, a change in both pitch and power is necessary to accomplish the desired change in the altitude of the aircraft.

4-8. Changes in Attitude Due to Power Variation

When power is varied to adjust airspeed, the aircraft tends to change attitude around all the axes of movement. As the airspeed is changing, the pitch and bank attitudes must be controlled so as to maintain a constant altitude and heading. Excessive power results in ★ **nose-low attitude** (at constant altitude) and increased airspeed (A, fig. 4-6); insufficient power results in a nose-high attitude and decreased airspeed (B, fig. 4-6). Also, when power is increased, the nose of the aircraft tends to yaw to the left except in single-rotor helicopters which yaw to the right.

4-9. Power Control

If the airspeed is changed, as in changing from slow cruise to normal cruise, more than normal cruise power may be used until reaching normal cruise airspeed. The reverse of this procedure is used when decreasing the airspeed. Overpowering and underpowering of manifold or torque pressure cause the airspeed to change at an increased rate, but provide ample time to trim the aircraft and smoothly adjust pitch and bank.

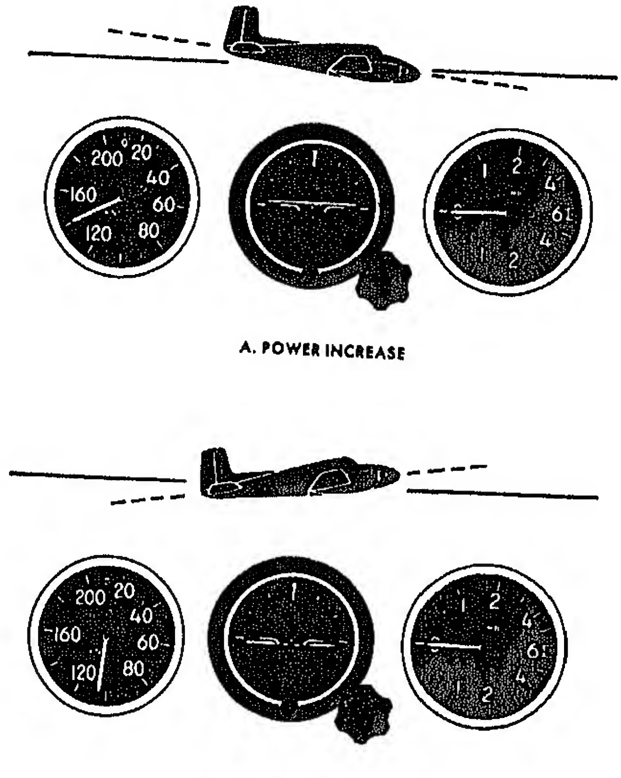

Figure 4-6. Maintaining a constant altitude/power variable.

4-10. Cross-Check of Power Instruments

In airplanes with constant-speed propellers, the tachometer and the manifold pressure gage need not be cross-checked immediately prior to power changes. During or immediately after a change has been made, the manifold pressure is cross-checked to determine the accuracy of the new setting or any necessary adjustments.

Section III. PITCH CONTROL

4-11. Pitch Control for Level Flight

The *pitch attitude* (fig. 4-7) of an aircraft is the angular relationship between the longitudinal axis of the aircraft and the actual horizon. The pitch attitude varies with changes in airspeed in level flight (para 4-8). A

change of several degrees in the angle of attack is necessary to maintain constant lift with changing airspeeds. At a given airspeed, the pitch attitude of the aircraft for level flight changes with a difference in load. Therefore, the angle of attack must be increased with increased load and decreased with decreased load. Instruments that indicate pitch attitude are—the attitude indicator, altimeter, vertical speed indicator, and airspeed indicator (fig. 4-8).

4-12. The Altimeter

The *altimeter* gives an indirect reading of pitch attitude in level flight. At a given power setting, the altimeter reading should remain constant, and any movement of the altimeter needle may be considered as giving an immediate indication of a change, or need for a change, in pitch attitude. If altitude is being lost, the nose is low (A, fig. 4-9); if altitude is being gained, the nose is high (B, fig. 4-9). Corrective action should be promptly initiated by using light pressures on the controls. If corrective action is delayed, the attitude may become extreme, necessitating greater control pressures.

4-13. The Attitude Indicator (Pitch Control)

The *attitude indicator* is used in conjunction with the altimeter as an aid in pitch control. It gives a direct and immediate indication of any change in pitch attitude of the aircraft. Using the attitude indicator, the nose of the aircraft can be placed in approximately the correct position for any desired pitch attitude.

a. In visual flight, the proper pitch attitude is attained by raising or lowering the nose in relation to the actual horizon. In instrument flight, the attitude indicator supplants the actual horizon; the same procedures used for visual flight are followed, by raising or lowering the nose of the miniature aircraft in relation to the horizon bar (fig. 4-10).

Figure 4-8. Pitch indicating instruments.

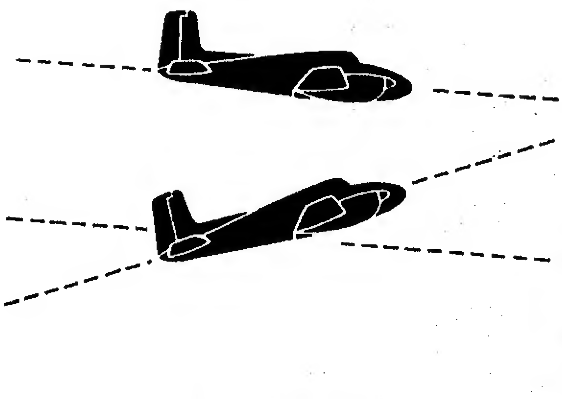

Figure 4-7. Pitch attitude.

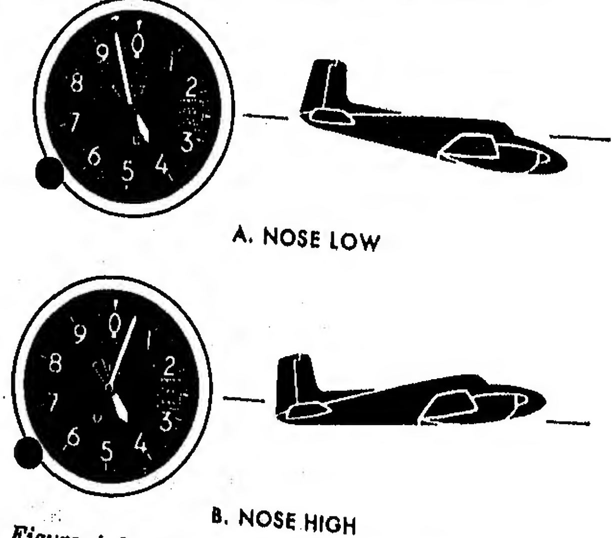

Figure 4-9. Altimeter indications of pitch attitude.

b. The miniature aircraft of the attitude indicator should be adjusted properly while on the ground (fig. 4-11). If, however, the miniature aircraft is not alined with the horizon bar when in level flight at normal cruising airspeed, it should be adjusted to indicate a level flight attitude. After adjustment, the miniature aircraft should be unchanged for varying airspeeds to insure a true picture of the pitch attitude at all times.

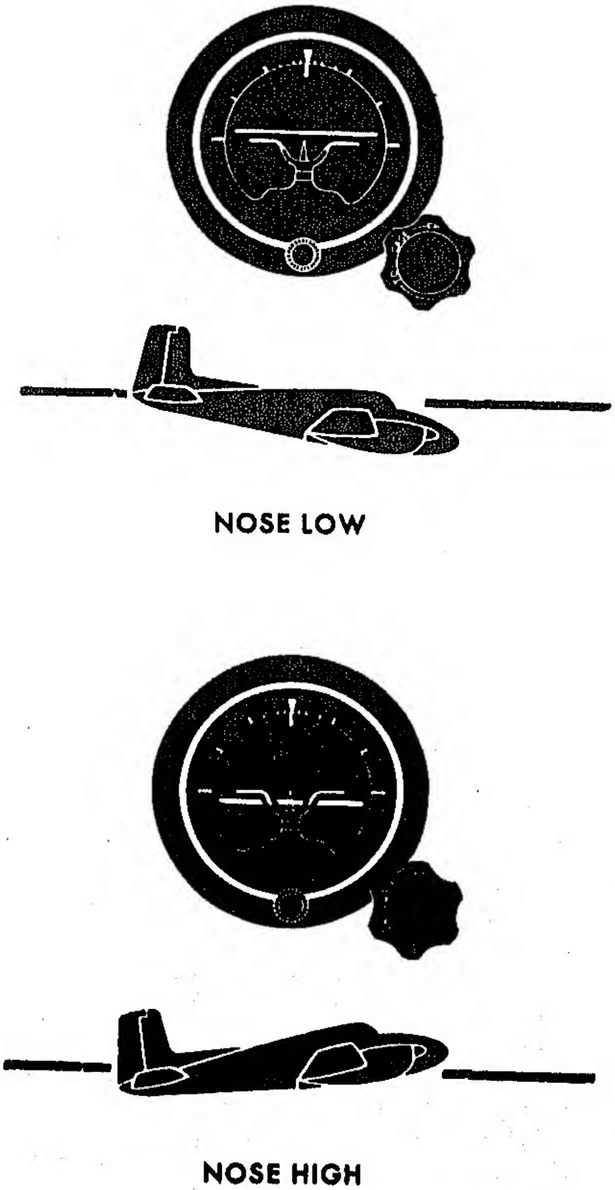

Figure 4-10. Attitude indicator showing indications of pitch attitude.

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c. When using the attitude indicator in applying pitch corrections, control pressure should be extremely light. Movement of the horizon bar above or below the miniature aircraft of the attitude indicator in fixed wing aircraft should not exceed one-half the bar width (A, fig. 4-12); in rotary wing aircraft, movement should not exceed one bar width (B, fig. 4-12). The vertical speed indicator is used to calibrate the attitude indicator. Any movement of more than 200 fpm (maximum initial pitch change) from the desired rate indicates overcontrolling. The attitude indicator should be checked at different airspeeds to determine the amount it has been moved to give a rate of 200 fpm. When corrections are made, the other pitch instruments are cross-checked to determine whether the pitch change was sufficient. If further change is required, an additional correction of not more than one-half the width of the horizon bar will normally counteract any deviation from normal flight.

d. Errors of the horizon bar during certain maneuvers give a misrepresentation (nose-high during acceleration or nose-low during deceleration). If ignored, discrepancies may result in controlling pitch to maintain a constant altitude. For a discussion of these errors, see paragraph 2.16*c*(2).

4-14. The Vertical Speed Indicator

a. The *vertical speed indicator* is used in conjunction with the altimeter and the attitude indicator to aid in pitch control (fig. 4-13). If the instrument is indicating zero when in level flight, any movement of the needle from the zero position requires an immediate change in the pitch attitude of the aircraft to return the needle to zero.

b. When movement of the vertical speed indicator is detected and immediate corrective pressure is applied to return the needle to zero, the altimeter usually will indicate no change in altitude. If the altimeter indicates a change in altitude, the amount of change governs the rate at which the aircraft is returned to the desired altitude. If the altitude is off 100 feet or less, the return rate should be no greater

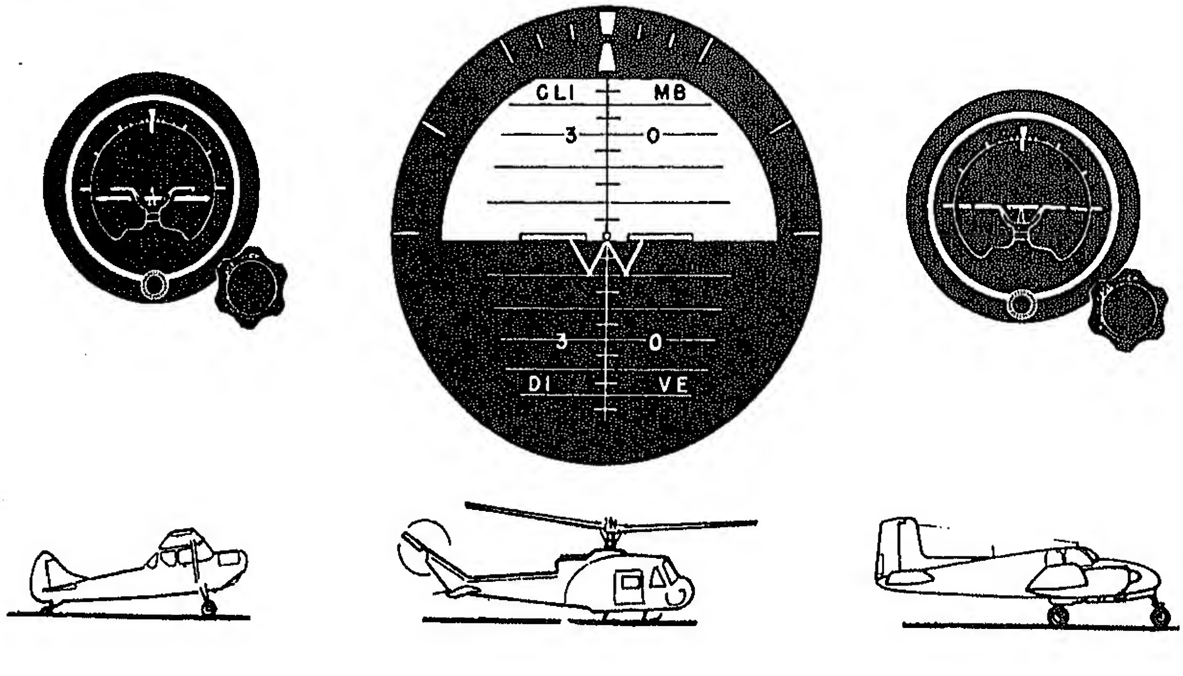

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Figure 4-11. Ground adjustment of the attitude indicator.

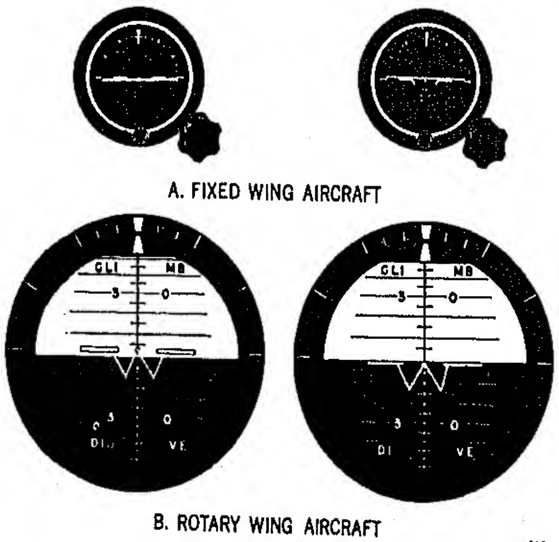

Figure 4-12. Initial pitch correction.

than 200 fpm. If the altitude is off more than 100 feet, a 500 fpm rate of climb or descent should be established and power adjusted.

c. If the vertical speed indicator shows a rate of 200 fpm or less, only slight pressure is needed to adjust it; however, if the deviation is more than 200 fpm, proportionally greater corrective pressure is required. After corrective pressure is applied, the altimeter and vertical speed indicator are cross-checked to determine any need for further corrections.

d. When pressure is applied to the controls and the vertical speed indicator shows a rate exceeding 200 fpm from that desired, overcontrolling is indicated. *For example,* if attempting to regain lost altitude at the rate of 500 fpm, a reading of more than 700 fpm will indicate overcontrolling. The initial movement of the needle indicates the trend of the vertical movement of the aircraft. The period of time necessary for the vertical speed indicator to reach its maximum point of deflection after a correction has been made is referred to as *lag.* The lag is proportional to the speed and magnitude of the pitch change. To make any adjustment in pitch attitude, a smooth control technique must be developed by using light pressures; the vertical speed indicator will thus be more easily interpreted. In fixed wing aircraft, overcontrolling may be reduced by relaxing pressure on the controls, which allows

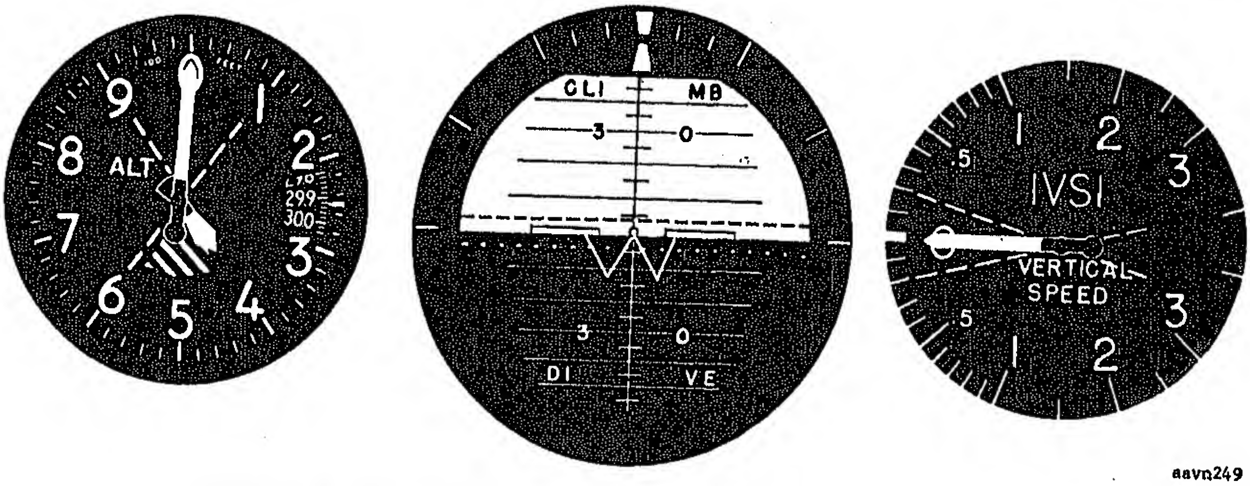

Figure 4–13. The vertical speed indicator as a pitch indicating instrument.

the pitch attitude to neutralize itself. In some rotary wing aircraft with servo-assisted controls, no control pressures are apparent. Under this condition, overcontrolling can be reduced by reference to the attitude indicator. Readjustment of the pitch attitude may be made by using the indications of the other pitch instruments.

e. Some aircraft are equipped with an *instantaneous vertical speed indicator* (IVSI). (The letters IVSI appear on the face of the indicator.) This instrument assists in interpretation by instantaneously indicating the rate of climb or descent.

f. Occasionally, the vertical speed indicator is slightly out of calibration and will indicate a slight climb or descent when the aircraft is in level flight. If readjustment cannot be accomplished, the error in the indicator should be considered when the instrument is used for pitch control. *For example,* an improperly set vertical speed indicator may indicate a descent of 100 fpm when the aircraft is in level flight. Any deviation from this reading would indicate a change in altitude.

4–15. The Airspeed Indicator

The *airspeed indicator* gives an indirect reading of the pitch attitude. With a given power setting and the correct attitude, the aircraft is in level flight and the airspeed remains constant (fig. 4–14). If the airspeed increases, the nose is low and should be raised (fig. 4–5); if the airspeed decreases, the nose is high and should be lowered. A rapid change in airspeed indicates a large change in pitch; a slow change in airspeed indicates a small change in pitch. Although the airspeed indicator is used as a pitch instrument, it may be used in level flight for power control. Changes in pitch are reflected immediately by a change in airspeed. There is very little lag in the airspeed indicator.

4–16. Pitch Trim

Incorrect setting of pitch trim (fig. 4–15) may result in a nose-high or a nose-low attitude unless corrective pressures are maintained.

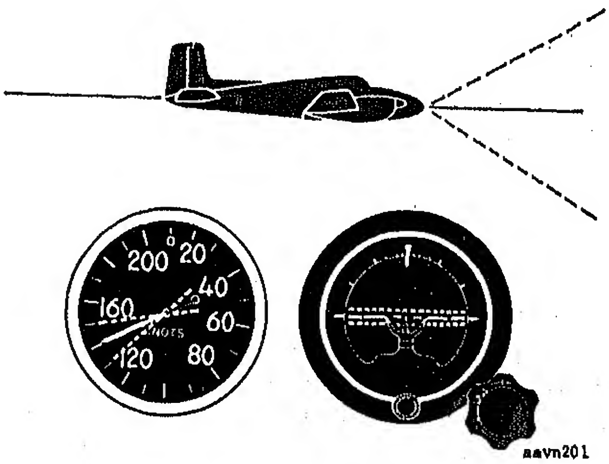

Figure 4–14. The airspeed indicator as a pitch indicating instrument.

a. Proper pitch trim may be made as follows:

(1) Establish desired attitude with control pressure.

(2) Relieve pitch pressure by application of trim while maintaining attitude.

(3) Repeat above procedures as necessary until the aircraft maintains an attitude without constant pressure on the control.

b. Some rotary wing aircraft have provisions for pitch trim and relief of control pressures. Trim adjustments on these aircraft should be made as follows:

(1) Press stick trim button or centering device release switch.

(2) Establish desired pitch attitude.

(3) Release stick trim button or centering device release switch.

(4) Repeat (1) through (3) above, as necessary.

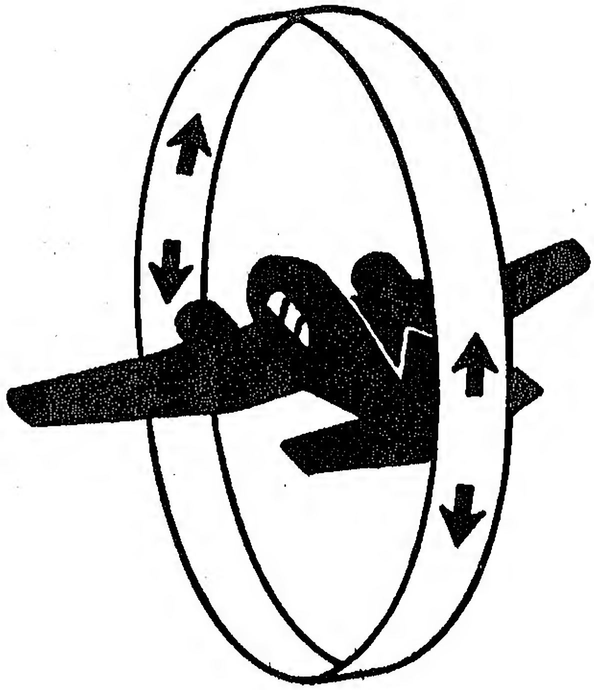

Figure 4-15. Pitch trim.

4-17. Cross-Check of Pitch Instruments

a. The altimeter is an important instrument for indicating pitch attitude in level flight except when used in conditions of exceptionally strong vertical currents such as thunderstorms. With proper power settings, any of the pitch instruments can be used to hold reasonably level flight attitude; however, only the altimeter will give the exact altitude information.

b. Regardless of which pitch instrument shows a deviation, a correction must be applied with a continuing cross-check to determine the effectiveness of the correction in maintaining a constant altitude. The sooner a need for a correction is observed, the smaller the amount of needed correction.

4-18. Common Errors in Pitch Control

Some common errors in pitch control are—

a. Overcontrolling.

b. Improper use of power.

c. Failure to cross-check the pitch instruments adequately and to take proper corrective action when need for a change in pitch attitude is indicated.

Section IV. BANK CONTROL

4-19. Bank Control to Produce Balanced Straight Flight

The *banking attitude* (fig. 4-16) of an aircraft is the angular relationship of the lateral axis of the aircraft to the actual horizon. To maintain a straight course in visual flight, the wings (rotor(s)) of the aircraft must be kept level with the actual horizon. In balanced flight, any deviation from a wings-level attitude produces a turn. During actual or simulated instrument conditions, the miniature aircraft and horizon bar of the attitude indicator are substituted for the real aircraft and the actual horizon, and the banking attitude is accurately indicated. Instruments which indicate banking attitude are the attitude indicator, the heading indicator, and the turn-and-slip indicator (fig. 4-16).

4-20. The Heading Indicator

The *heading indicator* (fig. 4-17) gives an immediate indication of turning. If straight flight is desired, corrective action must be applied as soon as a deviation in heading is detected. When available, the heading indicator is an important bank instrument during straight flight.

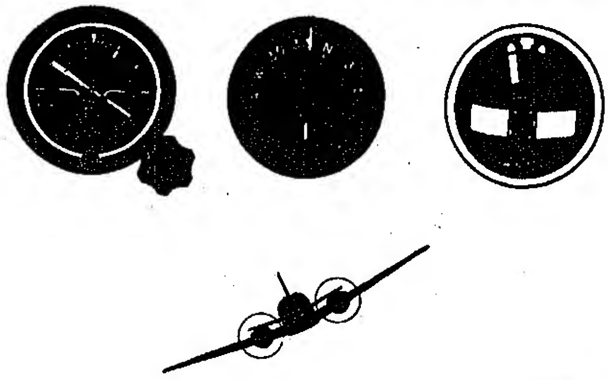

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Figure 4-16. Bank indicating instruments.

4-21. The Attitude Indicator (Banking Attitude)

The banking attitude is shown directly on the attitude indicator (fig. 4-18). If the aircraft starts to turn, the turn can be stopped by leveling the wings of the miniature aircraft with reference to the horizon bar. In fixed wing aircraft, this should be done (without slipping or skidding) by coordinated use of ailerons and rudder. In rotary wing aircraft, it is accomplished by coordinated use of cyclic control and pedals.

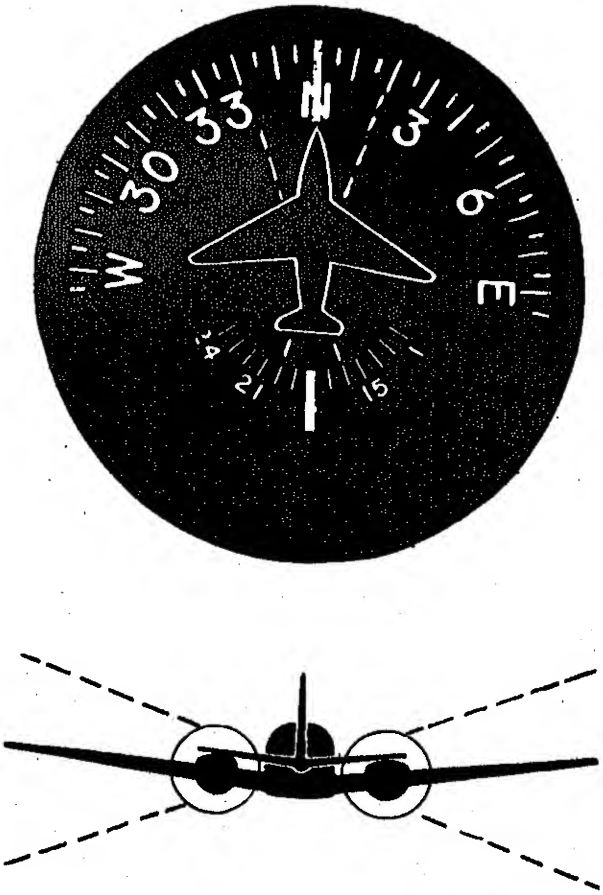

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Figure 4-17. The heading indicator as a bank-indicating instrument.

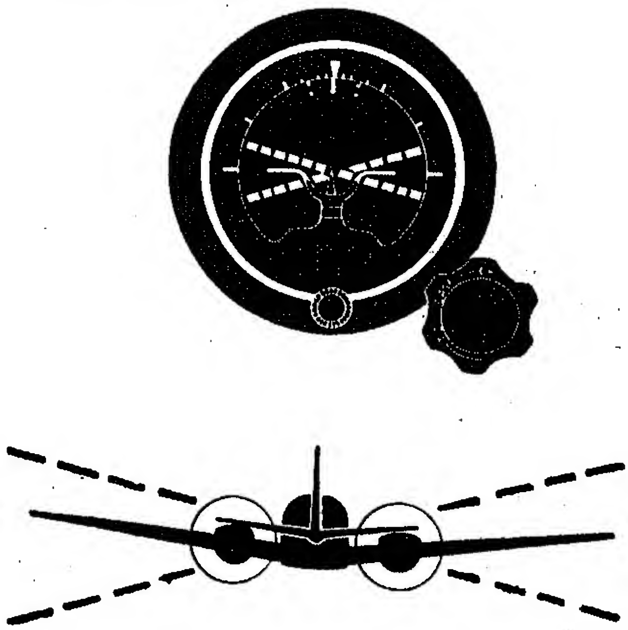

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Figure 4-18. The attitude indicator as a bank-indicating instrument.

4-22. The Turn-and-Slip Indicator

When the heading indicator and attitude indicator are not available, the turn-and-slip indicator is used as the bank instrument.

a. Turn Needle. The turn needle indicates rate of turn. If the turn needle of the turn-and-slip indicator is exactly centered, the aircraft is in straight flight; if it is displaced

from center, the aircraft is turning in the direction of displacement. Recentering the needle will again return the aircraft to straight flight. When any deviation from the exact center position is observed, it must be promptly recentered to prevent turning (fig. 4–19). Accurate interpretation of the needle position requires close observation. In turbulent air the needle will oscillate from side to side and accurate interpolation of these fluctuations must be made to detect actual turning. If the deflection is equal on both sides of center, the aircraft is flying straight. If the distance of deflection is greater on one side than the other, the aircraft is turning in the direction of the greater deflection.

b. Turn-and-Slip Indicator Ball. Although the ball is combined with the turn indicator as one unit, it is a separate and independent instrument, with its own specific function. The two parts of the turn-and-slip indicator are, however, normally read and interpreted together. If the ball is off-center, the airplane is yawing (slipping or skidding). If the aircraft is slipping, the ball is off-center toward the inside of the turn (low wing) (A, fig. 4–20); if skidding, the ball is off-center toward the outside of the turn (high wing) (B, fig. 4–20). The ball of the indicator shows the quality of control coordination (C, fig. 4–20), whether in turning or straight flight.

4–23. Bank Trim

a. In fixed wing aircraft, an incorrect setting of the aileron trim tab is reflected in a wing-low tendency. This results in a tendency of the aircraft to turn unless the aileron and rudder trim tabs (fig. 4–21) neutralize each other and produce a slip on a constant heading.

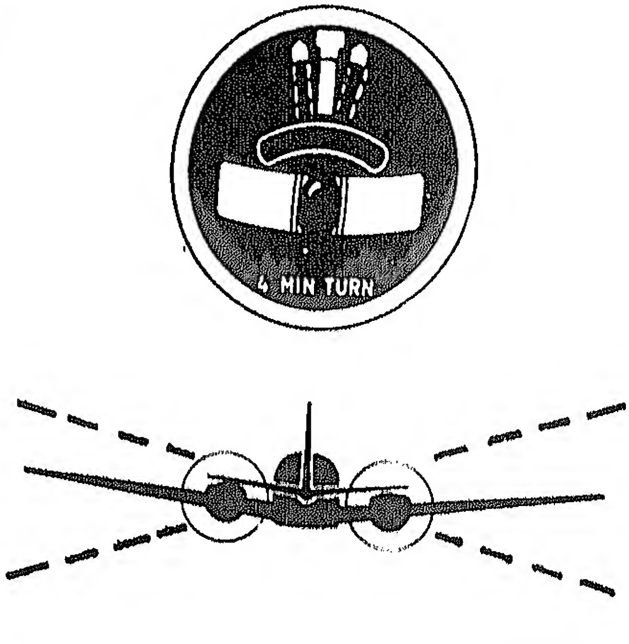

Figure 4–19. The turn-and-slip indicator as a bank-indicating instrument.

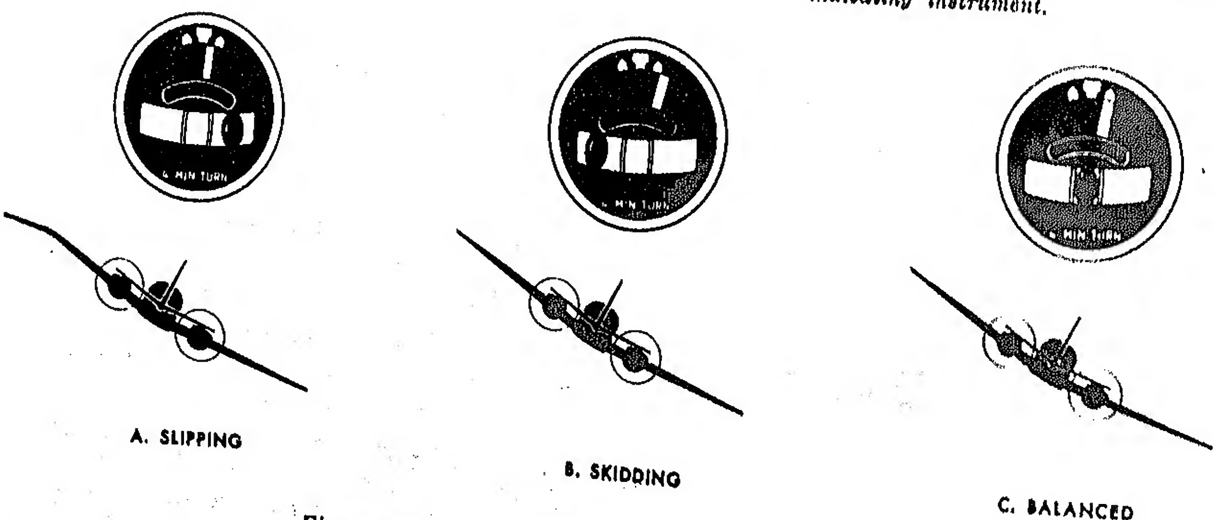

Figure 4–20. Instrument indications of quality control.

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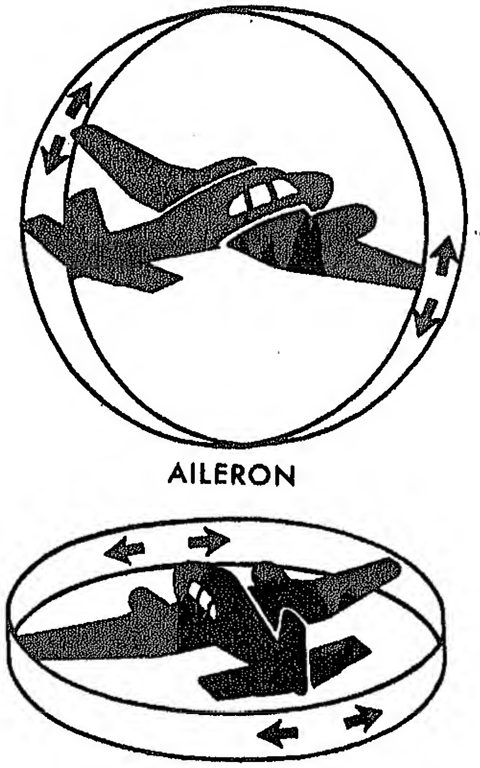

Figure 4-21. Rudder and aileron trim.

b. An incorrect setting of the rudder trim results in a tendency to skid gradually out of a straight flightpath. A skid usually causes the aircraft to bank because it increases the velocity and, therefore, the lift of one wing. Accurate trim adjustment facilitates precise bank control.

c. Rudder and aileron trim adjustments in fixed wing aircraft should be made as follows:

(1) Establish balanced flight in the desired attitude with control pressures.
(2) Relieve aileron pressure with aileron trim.
(3) Relieve rudder pressure with rudder trim.
(4) Repeat process until the aircraft will maintain desired attitude.

d. Rotary wing aircraft equipped with trim mechanisms should be trimmed as follows:

(1) Press stick trim button or centering device release switch.
(2) Establish level flight with cyclic control with reference to the attitude indicator.
(3) Center the ball of the turn-and-slip indicator with pedals.
(4) Release stick trim button or centering device release switch.
(5) Repeat (1) through (4) above, as necessary.

4-24. Cross-Checking of Bank Instruments

All available bank instruments are used to indicate straight flight. In balanced flight, a constant heading can be maintained by reference to the heading indicator and by keeping the wings level with reference to the attitude indicator. Without the heading indicator or the attitude indicator, straight flight can be maintained by reference to the turn-and-slip indicator. As the use of each bank instrument is learned, the instrument should be included in the sequence of cross-checking. As the number of instruments to be observed increases, the speed of cross-checking must also increase.

4-25. Common Errors in Bank Control

Common errors in bank control are—

a. Failure to cross-check the heading indicator to maintain straight flight.

b. Failure to make corrective action promptly to return to the desired heading.

c. Failure to use attitude indicator properly.

d. Failure to control the turn needle properly when using the turn-and-slip indicator.

e. Incorrect pressures being exerted on rudders, ailerons, pedals, or cyclic control.

4-26. Instrument Interpretation and Cross-Checking

Proper cross-checking and instrument interpretation are vital, even in visual flight. During instrument flight, the instruments serve a dual purpose—they provide (1) a reference of the attitude of the aircraft, and (2) an indication of whether that attitude will produce the desired performance. The control technique is identical to that in visual flight. A good instrument pilot interprets instruments rapidly and accurately.

CHAPTER 5

BASIC INSTRUMENT MANEUVERS

Section I. FIXED WING

5-1. General

Basic instrument maneuvers are those taught to obtain proficiency in cross-checking, instrument interpretation, and control techniques. Climbs and descents are standard at 500 fpm and slow cruise airspeed. Unless otherwise indicated, all turns are assumed to be standard rate (3° per second).

5-2. Introduction

Except where otherwise indicated, the method of performing each maneuver discussed in this section presupposes emergency panel. Using emergency panel, one or more of the flight instruments is assumed to be inoperative and is simulated by covering the appropriate instrument(s). For training purposes, the heading indicator (gyro) and attitude indicater are generally covered. Basic maneuvers are performed using emergency panel in order to acquaint the aviator with a means of performing safe flight if gyro instruments become inoperative. This training also develops smooth control technique and increases the aviator's speed in cross-checking.

5-3. Instrument Takeoff

The instrument takeoff (fig. 5-1) is becoming more and more important as the day of all-weather flying approaches. Aviators should be proficient and fully confident in their ability to take off without any visual references other than the flight instruments. Instrument takeoff techniques vary slightly with different types of aircraft. The method outlined in *a* through *c* below applies to any type of aircraft if the original attitude on the ground is considered.

a. The aircraft should be allowed to roll straight for a short distance on the runway (fig. 5-1) to assure that the nosewheel or tailwheel is properly alined. The brakes should be held firmly to prevent creeping, and the throttle(s) advanced to slightly above idling. The heading indicator should be checked for proper functioning for the takeoff. The brakes should be fully released and throttle(s) advanced smoothly to takeoff power. After the brakes are released, the heading indicator *must* be checked frequently to maintain a proper heading. Any deviation in the desired heading should be corrected immediately. As the proper airspeed is reached, the pitch attitude should be adjusted as necessary to allow the aircraft to climb off the ground.

b. After takeoff, normal climbing attitude should be established on the attitude indicator, and a cross-check for proper indications should be made, to include altimeter, airspeed, heading indicator, and vertical speed indicator. As the aircraft leaves the ground, the attitude indicator should be observed carefully in order to hold the correct pitch attitude and keep the wings level. A variation from correct pitch attitude at this time may cause the aircraft to settle, to descend, or to climb at low airspeed. Directional control is maintained by reference to the heading indicator. The altimeter and airspeed indicators should show a steady increase, and the vertical speed indicator a steady indication of a climb.

c. Errors common in instrument takeoff include—

(1) Improper alinement on the runway.
(2) Improper use of power.
(3) Overcontrolling.

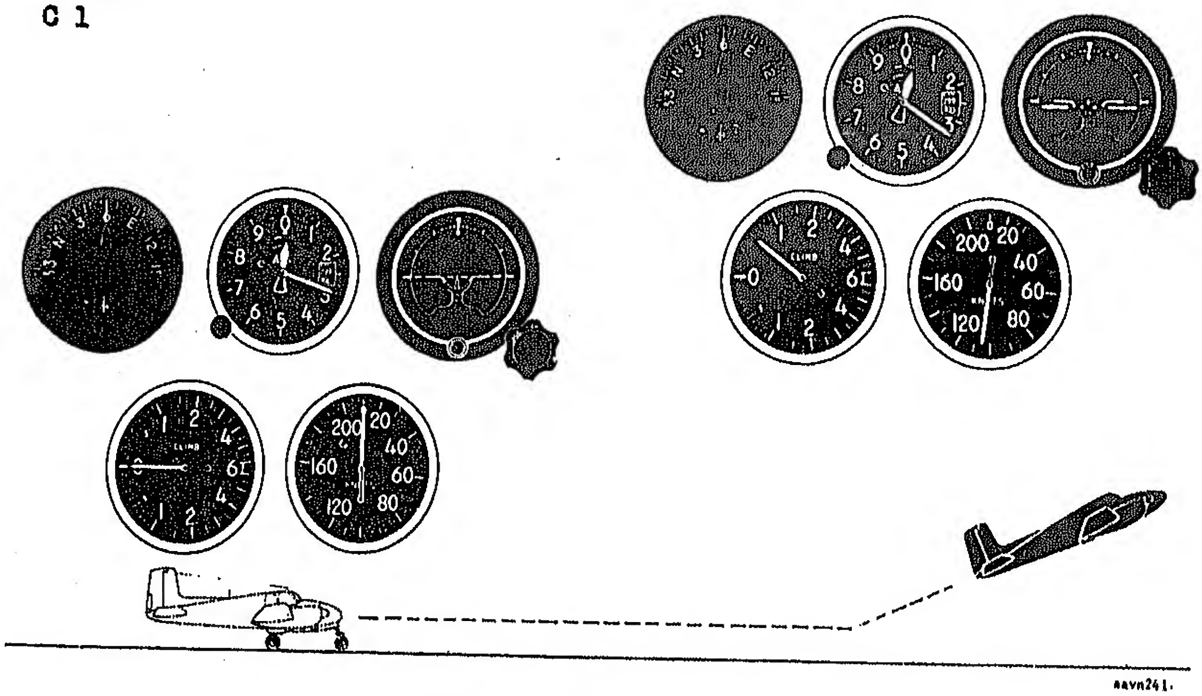

Figure 5-1. The instrument takeoff.

(4) Unnecessary use of brakes.
(5) Failure to cross-check the instruments.
(6) Failure to maintain correct attitude after takeoff.

5-4. Straight and Level Flight

a. Perfect straight and level flight is possible only under ideal conditions, which rarely exist. Turbulence causes changes in the aircraft's attitude, altitude, and heading (fig. 5-2). In every flight attitude, the forces acting on the aircraft have a definite relationship. These forces (lift, weight, drag, and thrust) must be in balance for straight and level, unaccelerated flight. When one instrument indicates a need for an adjustment in attitude to maintain a given performance, other instruments will show the amount and direction in which the adjustment should be made. For example, if the airspeed indicator shows a decrease in airspeed, the altimeter or the manifold pressure gage will indicate the adjustment to be made either in attitude or power to restore airspeed and/or altitude.

b. Any deviation from the desired heading will be shown on the heading indicator. For deviations of 20° or more, the return to the desired heading should not exceed a standard rate turn. For heading corrections of less than 20°, use half-standard rate turn or with full panel, the bank should equal the degrees of turn to be accomplished, but not to exceed the number of degrees of bank required for a standard rate turn. Any time an instrument indicates a change in performance, necessary adjustments should be made. Instead of watching a particular instrument to see the effects of the adjustment, the cross-check should continue while performance is being corrected. In this way, the total effect of the adjustment to

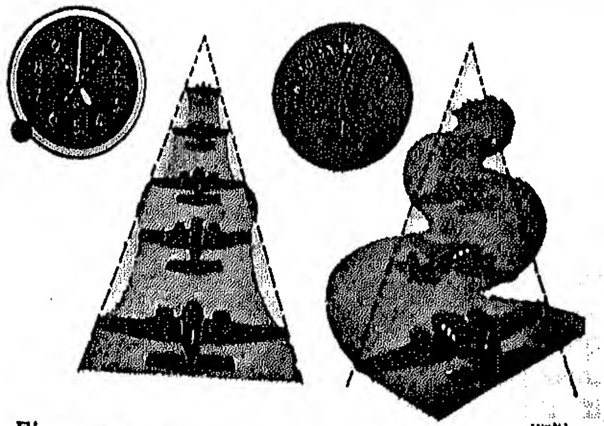

Figure 5-2. Maintaining straight and level flight.

performance can be seen through the entire panel. An aircraft normally will remain in any given attitude only for a short period of time, even though trim is set properly for that attitude. By the time a complete cross-check has been completed and the necessary adjustments to performance have been made, another cross-check must be initiated.

c. Errors common in straight and level flight include—

(1) Failure to maintain a heading.
(2) Failure to maintain altitude.
(3) Failure to use proper power settings.
(4) Poor aircraft control.
(5) Cross-check too slow.

5-5. Straight Climbs and Descents

a. Power and pitch attitude control performance in airspeed and altitude. To enter a climb from cruising airspeed, the pitch attitude is adjusted to the approximate rate of climb desired. Very little back pressure is required to complete the transition from level to climbing attitude. As soon as back pressure is applied, the vertical speed indicator indicates climb. Unless the instantaneous vertical speed indicator is installed, several seconds may be required for the vertical speed indicator to indicate the correct rate (fig. 5-3). Once the rate is established, it should be held constant. During the transition, airspeed will slowly dissipate to climbing airspeed. As airspeed approaches climbing airspeed, power is increased to the climb power setting. Smooth control technique must be used to avoid overcontrolling and "chasing" the vertical speed indicator. Proper trim technique should be used throughout the climb. Large changes in power and pitch necessitate large changes in control pressure. Difficulty may be encountered with directional control unless prompt action is taken to counteract torque effects when power or airspeed is changed.

b. When leveling off from a climb, it is necessary to start adjusting pitch attitude prior to reaching the desired altitude. The amount of lead varies with the rate of climb of the aircraft and individual technique. When leveling off, the effect of pitch change will be shown by the reduced rate on the vertical speed indicator and the stopped or reduced needle movement of the altimeter. Observing the trend of the vertical speed indicator aids in leveling off at the desired altitude. If normal cruise is desired, the climb power should be held until approaching cruising speed. As the airspeed increases, a constant change in pitch is necessary to maintain a constant altitude. As the airspeed approaches cruising speed, power is smoothly reduced to the proper power setting.

c. Before starting a descent (fig. 5-3), power is reduced to the descent power setting. Altitude is maintained until descending airspeed is reached. The descent is established with reference to the vertical speed indicator, and airspeed is maintained with power. To level off from the descent at the desired altitude, the lead techniques are essentially the same as leveling off from a climb. One of two alternatives governs the procedure to be followed—

(1) At times, as in a low approach, approach speed should be maintained by advancing power to the appropriate setting for level slow cruise and adjusting pitch attitude to maintain the desired altitude.
(2) To level off at normal cruise, the techniques are the same except that power is increased to the cruise setting.

d. Errors common in straight climbs and descents include—

(1) Failure to control airspeed when entering a climb or descent.
(2) Overcontrolling pitch attitude.
(3) Failure to maintain heading.
(4) Improper power settings.
(5) Improper lead when leveling off.

5-6. Level Turns

a. Entry into a level turn (fig. 5-4) is accomplished by coordinated pressure on the ailerons and rudder to produce balanced flight in the direction of the desired turn. As pressure is applied, the attitude indicator will show the degrees of bank and the turn-and-slip in-

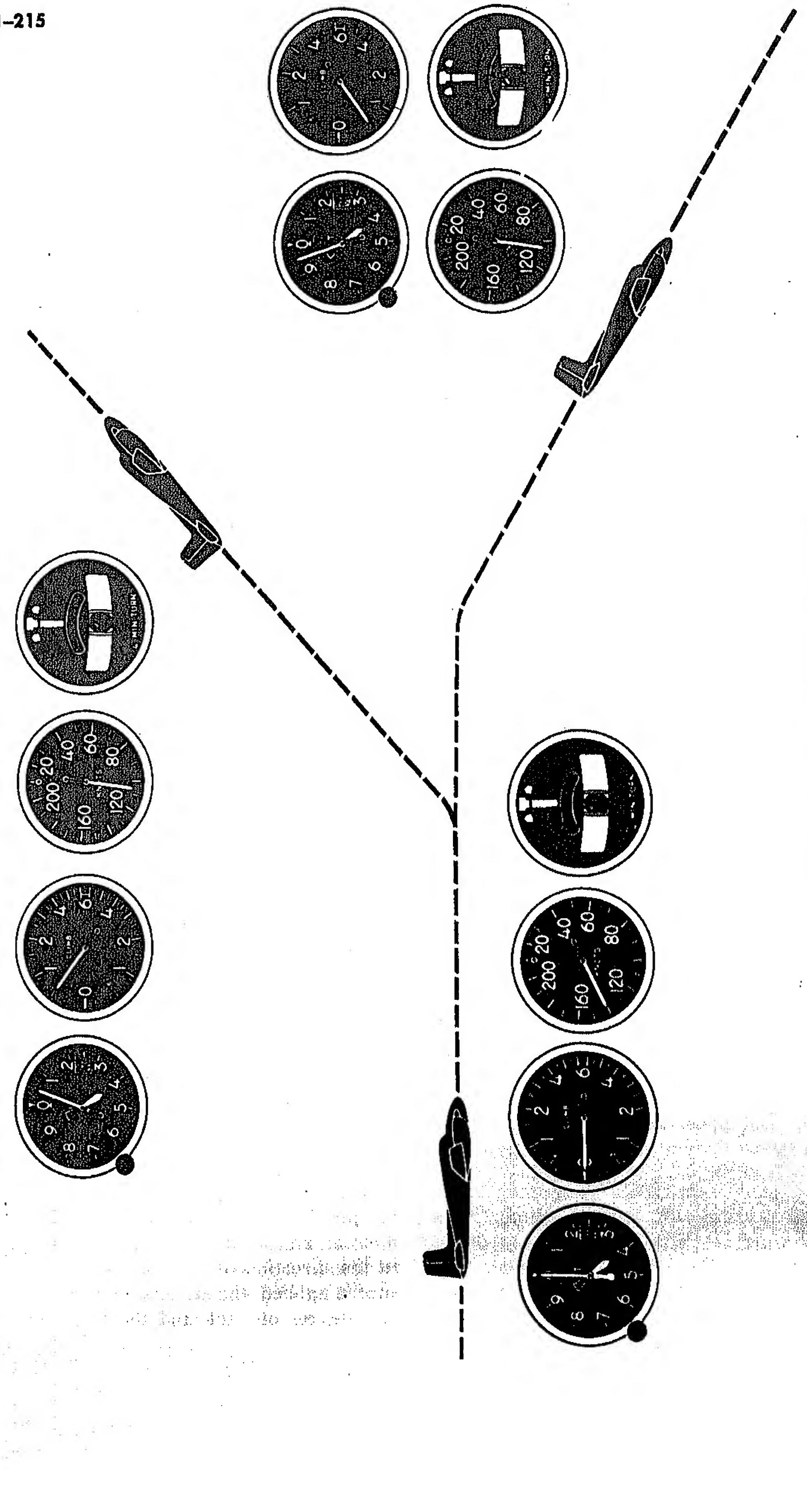

Figure 5-3. Straight climbs and descents.

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dicator will show the direction and rate of turn. During entry into a turn, the pitch attitude must be changed to compensate for the loss of vertical lift caused by banking the aircraft; therefore, the pitch instruments must be observed closely while rolling into a turn. Corrective action should not be applied until the instruments indicate a deviation from the desired performance. As the nose is raised to hold altitude, power must be added if a constant airspeed is to be maintained (fig. 5-4). Maintaining the desired rate of turn is very important. Any change in bank changes the vertical component of lift, thus necessitating a change in pitch to maintain level flight.

b. To recover to straight and level flight, coordinated pressure is applied on the ailerons and rudder in the opposite direction of turn. As the amount of bank is decreased, the pitch attitude must be adjusted to maintain a constant altitude. At the same time, power should be reduced to prevent the airspeed from increasing. The rate of roll-in and rollout should be the same.

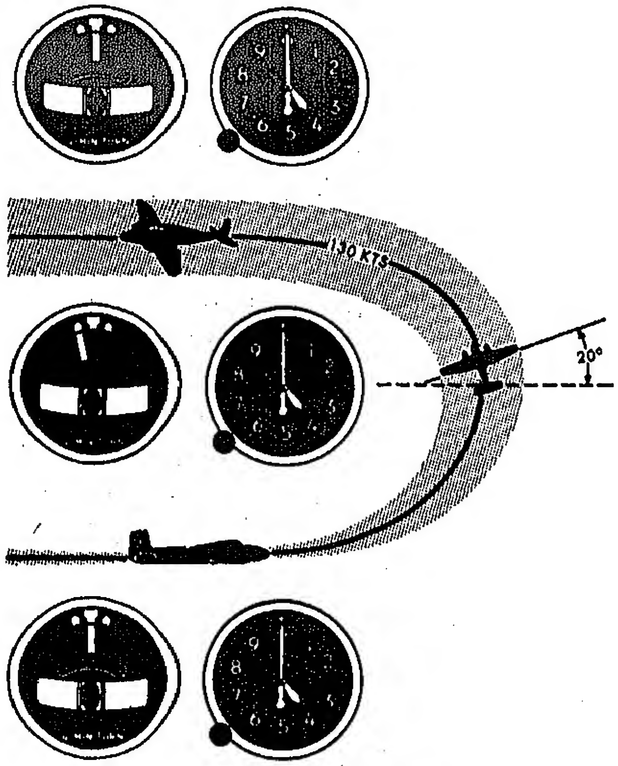

Figure 5-4. Level turns.

c. Errors common in level turns include—

(1) Failure to coordinate aileron and rudder pressures during the entry and recovery.

(2) Changing the pitch attitude of the aircraft before it is necessary.

(3) Failure to maintain a constant rate of turn.

(4) Excessive use of the rudders.

(5) Rolling in and out of turns too rapidly.

5-7. Climbing and Descending Turns

a. This maneuver combines climbs and descents with turns, and requires a more rapid cross-check. For precise execution, rate of climb or descent and rate of turns should be checked against time. Before starting the maneuver, the airspeed is reduced either to climbing or descending airspeed while maintaining straight and level flight. When desired airspeed is established, a climbing or descending turn is entered. The banking attitude and rate of turn are controlled by reference to the attitude and/or turn-and-slip indicator. Control of power and pitch attitude is the same as in a straight climb or descent. Corrections are made in a rate of turn and vertical speed as necessary. When the allotted time has elapsed, the altitude and heading should be such that a level-off from the climb or descent and recovery from the turn will result in the desired heading and altitude. Regardless of the time factor, the level-off and rollout should be on the desired altitude and heading.

b. Errors common in climbing and descending turns include—

(1) Failure to detect a need for a change in rate of turn or vertical speed.

(2) Overcontrolling power, pitch, or bank.

(3) Those associated with climbs, descents, and timed turns.

5-8. Steep Turns

a. Any turn greater than standard rate or 30° bank is considered a *steep* turn. The rate of turn may be determined by the attitude or turn-and-slip indicator. A 4-minute turn needle should indicate a minimum of a 3-needle width

deflection, while a 2-minute turn needle should indicate a minimum of a 1½-needle width deflection. This type of turn is seldom necessary or advisable in instrument weather, but is a good test of the ability of the aviator to react quickly and smoothly to changes in attitude of the aircraft. Regardless of the degree of bank, the techniques of entry and recovery are the same in steep turns as in any other turns. When the bank is steep, however, it is more difficult to control the pitch attitude with elevator control alone. If not compensated for during bank changes, a change in vertical lift component results in a large deviation in altitude. During roll-in, back pressure on the elevator control is applied to maintain a constant altitude, and power is increased to maintain a constant airspeed. As the aircraft is rolled out of the bank, back pressure should be released or trim adjusted to maintain altitude; and power should be decreased to maintain a constant airspeed. If the roll-in and rollout are made at the same smooth rate as in standard rate turns, there should be no difficulty in controlling the pitch and power. An abrupt rollout requires rapid changes, in pitch attitude to keep the aircraft from climbing above the desired altitude. The use of instruments is the same as in standard rate turns except that the speed of cross-check must be increased.

b. Errors common in steep turns include—

(1) Failure to maintain altitude.
(2) Failure to maintain proper airspeed.
(3) Improper power and pitch control during entry and recovery.
(4) Improper bank and pitch control.

5–9. Timed Turns

a. In a *timed* turn, the heading of the aircraft is changed a definite number of degrees with reference to the clock and the turn needle. It may be easiest to start the timing when the second hand is at the 12-, 3-, 6-, or 9-o'clock position.

b. The turn needle is checked for error prior to starting timed turns. To check the turn needle, the approximate angle of bank for a standard rate turn is established with reference to the attitude indicator. Necessary changes are made to produce an indication of a standard rate turn with reference to the turn needle.

c. Exact timing is very important. If the turn needle is in calibration, 10 seconds will produce a change in heading of 30°. Any deviation is corrected by changing the angle of bank to position the turn needle so that a turn of 3° per second (standard rate) results.

d. Timed turns are normally entered from straight and level flight. To enter a timed turn, heading is maintained until the second hand arrives at the desired position, then the roll-in is started.

e. The number of degrees to be turned governs the length of time and rate of turn. Turns of 20° or more should be made at standard rate; less than 20°, at half-standard rate. Normally, turns to predetermined headings will be in the shortest direction of turn. *For example,* starting a timed turn from heading of north (A, fig. 5–5) and turning to a heading of 120° (B, C, and D, fig. 5–5) would take 40 seconds plus rollout. If the time and the roll-in were started with the second hand in the 12-o'clock position, the rollout would be started when the second hand is on the 40-second position (C, fig. 5–5). The same rate of rollout is used as was used to roll into the turn (B, and D, fig. 5–5). When using half-standard rate turn, compute for standard rate and double the time to turn.

f. Errors common in timed turns include—

(1) Improper direction of turn.
(2) Improper rate of turn.
(3) Failure to enter and recover from timed turns at the same rate.
(4) Failure to compute time correctly for turns.

5–10. Compass Turns

a. The magnetic compass is the only direction-indicating instrument in some airplanes. However, the inherent characteristics of the compass must be understood to be able to turn the aircraft to a magnetic heading and maintain it.

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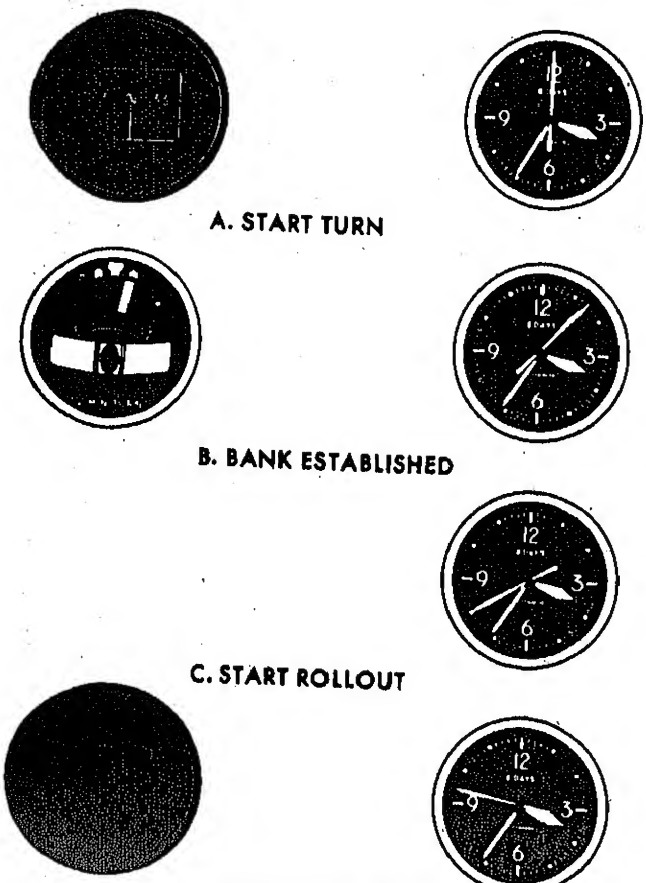

Figure 5-5. Timed turns.

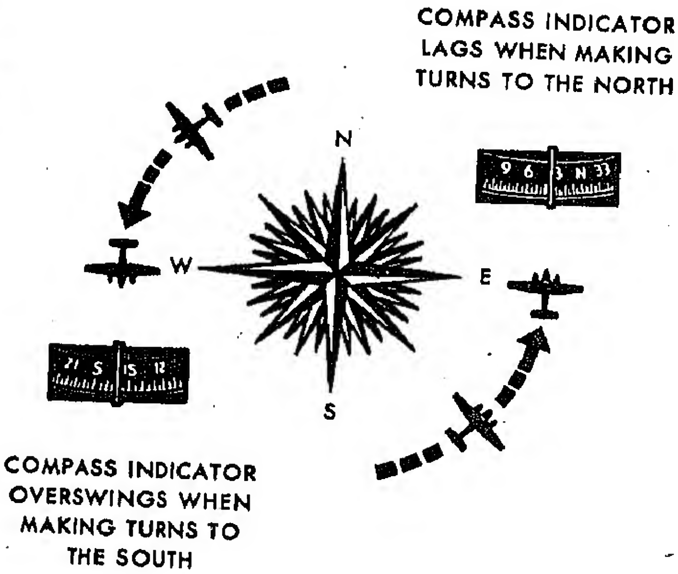

Figure 5-6. Compass turns.

b. With an angle of bank between 15° and 18° the amount of lead or lag to be used when turning to headings of north and south varies with, and is approximately equal to, the latitude of the locality over which the turn is made. This lead or lag is at a minimum over the Equator and increases as the latitude increases, reaching its maximum at the polar regions. The angle of bank must be accurately held to attain success in turns to magnetic compass headings. The compass reading is reliable only when the aircraft is in a wings-level and constant-pitch attitude at a constant airspeed.

c. In the northern hemisphere, when turning to a heading of north, the rollout lead must be the number of degrees equal to the latitude plus one-half the angle of bank used in the turn (fig. 5-6). For example, during a left turn to a heading of north in a locality where the latitude is 30° and the angle of bank is 15°, the rollout should be started when the magnetic compass reads 37.5° (30° plus one-half of 15°). To turn to a heading of south, the aircraft must be turned past south the number of degrees equal to the latitude minus one-half the angle of bank used in the turn (fig. 5-6). For example, when turning to the right to a heading of south, the rollout is started when the magnetic compass reads 202.5° (180° plus 30° minus 7.5°). When turning to a heading of east or west from a northerly heading, the rollout is started approximately 10° before the heading is reached. When turning to a heading of east or west from a southerly heading, the rollout is started approximately 5° before the heading is reached. When turning to other than cardinal headings, the lead or lag must be interpolated. South of the Equator, lead and lag are reversed.

d. Errors common in compass turns include—

(1) Failure to level the wings upon completion of turn.

(2) Failure to maintain an angle of bank of 15° to 18°.

(3) Failure to maintain proper attitude.

(4) Failure to maintain constant airspeed.
(5) Improper computation of rollout point.

5-11. Turns to Headings (Gyro)

a. Control techniques used in turns to headings with reference to the heading indicator are the same as level turns (para. 5-6). If the attitude indicator is available, the angle of bank should be limited to the angle needed for a standard rate turn but should not exceed the number of degrees to be turned. If the attitude indicator is not available, use a standard or half-standard rate of turn, as appropriate. To rollout on a given heading, the rollout must be started before the desired heading is reached (fig. 5-7). The amount of lead varies with the amount of bank and individual techniques. The heading indicator is checked after the wings are level to determine whether the proper amount of lead has been used. A variation from the desired heading would indicate a need for a change in lead. If the attitude indicator is available, 1° of lead for every 2° of bank should be used as a guide. If the attitude indicator is not available, the number of degrees used on rollout should be the same as the number of degrees used on roll-in.

b. Errors common in turns to headings (gyro) include—
(1) Failure to use proper lead in rollout.
(2) Improper rate of rollout.
(3) Failure to use proper bank for number of degrees to be turned.

5-12. Unusual Attitudes and Recoveries

a. An *unusual attitude* is any attitude of the aircraft not required for normal instrument flight. An unusual attitude may result from any one or a combination of several factors such as turbulence, vertigo, instrument failure, confusion, or distraction from flight instruments.

b. Once an unusual attitude has been detected, the airplane should immediately be returned to normal flight positively and with a minimum change of altitude. Altitude is a safety factor, and common sense demands that as much altitude as possible be retained.

c. The recovery from any unusual attitude is initiated by using the airspeed indicator, the altimeter, turn-and-slip indicator, the vertical speed indicator, or non-spillable attitude indicator, if available. Due to lag, the vertical speed indicator is disregarded during the initial part of the recovery. If the airspeed is above the desired airspeed and is increasing, power

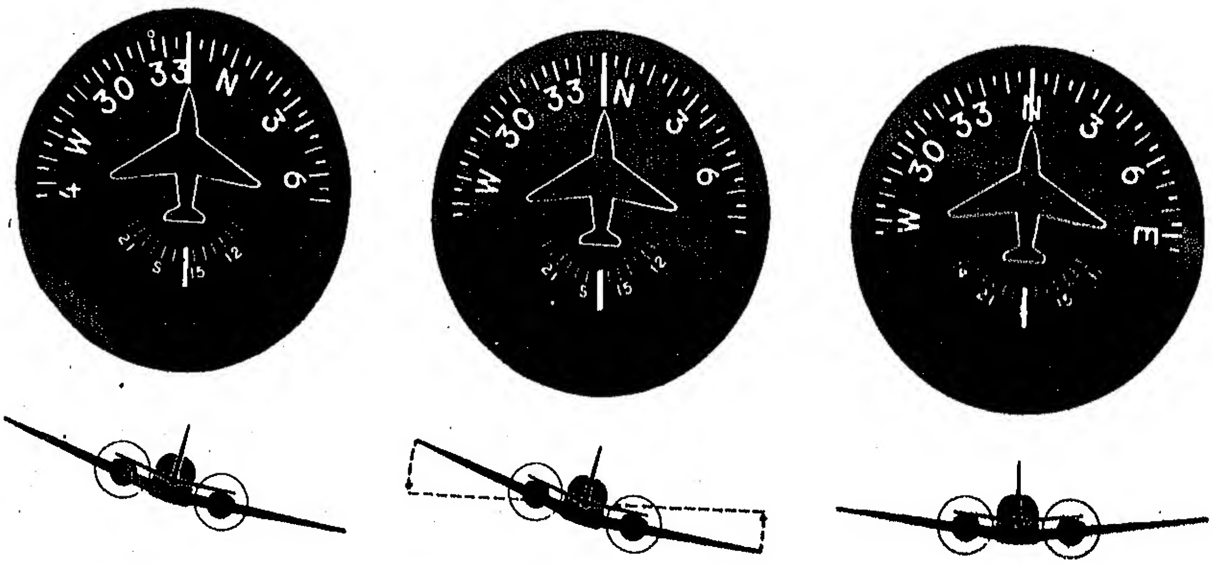

Figure 5-7. Turns to headings (gyro).

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should be reduced as necessary to prevent additional increase in airspeed and loss of altitude; then the bank and pitch attitude are corrected to maintain level flight. All components of control are changed almost simultaneously with only a slight lead of one over the other. When the initial control correction has been applied without benefit of an attitude indicator, the instruments must be observed closely to avoid overcontrolling, since the required control pressure might be heavy. Pressure is applied smoothly until the altimeter and airspeed indicators show level flight attitude by needle movements stopping. The banking attitude is shown by the turn needle.

d. If the airspeed is below the desired airspeed and decreasing, pitch and power should be adjusted as necessary to regain control airspeed. Then pitch, bank, and power are corrected to maintain a level flight attitude.

e. A spin is indicated by low airspeed and full displacement of the needle in the direction of the spin and the ball displaced in the opposite direction. In recovering from a spin, the normal visual flight procedure is employed. Once the spin has been stopped, the remainder of the recovery is the same as from a high airspeed recovery.

f. Because of the very nature of the occurrence of an unusual attitude, prompt corrective action is essential. Excessive loss of altitude is undesirable and may be dangerous. A climb or descent back to the original altitude and heading is started as soon as recovery has been accomplished.

g. Rules for recovering from unusual attitudes are as follows:

(1) If the aircraft is in a nose-low attitude, power is reduced as necessary while correcting bank and pitch attitude.

(2) If the aircraft is in a nose-high attitude, power is increased as necessary while correcting pitch and bank attitude.

h. Errors common in unusual attitude recoveries include—

(1) Failure to adjust power when noting a critical airspeed condition.

(2) Failure to detect level flight attitude.

(3) Failure to establish level flight attitude.

(4) Using sense of *feel* instead of instruments.

Section II. ROTARY WING

★5-13. Introduction

Since the advent of helicopter flight, field commanders have been desirous of using helicopters in all weather conditions to gain tactical advantage and the element of surprise through increased mobility.

a. The basic principle of helicopter instrument flight under any and all weather conditions stems from the application of fundamentals for VFR helicopter flight. The only two elements of control in all aircraft are the attitude of the aircraft to the horizon and the power applied. Therefore, all maneuvers and exercises of flight requirements must be based solidly upon attitude and power control references. Airspeed is a result of attitude control. Altitude is a result of power control. To properly change to or hold any desired altitude, the aviator must have a tentative estimate of basic power settings for climb, cruise, and descent.

b. The maneuvers discussed in this section are designed to develop proficiency in the attitude control of rotary wing aircraft, and can be considered as the first step in fulfilling the requirement of all-weather operations.

c. The method of performing each maneuver presupposes full panel and emergency panel, with the exception of instrument takeoff. Emergency panel is simulated by covering one or more flight instruments.

★*d.* Approximate airspeeds and power settings for rotary wing aircraft presently being used for instrument flying are found in tables IV, IV.1, and VII (tables II, III, V, and VI are rescinded). Because of the power requirements under varying loads, these tables are to be used only as general guides.

Table IV. Approximate Airspeed and Power Settings—Rotary Wing Aircraft (UH-1B)

Aircraft	Maneuver	Airspeed (knots)	Torque psi	rpm
UH-1B	Takeoff	-----	*5	6,600
IROQUOIS	Climb	80-90	29	6,600
(7,600-8,000	Normal cruise	90	24	6,600
lbs.)	High cruise	100	26	6,600
(Gross)	Slow cruise	70	20	6,600
	Descent	80-90	18	6,600

*Plus hovering power.

Note. All of above settings are approximate and are based on gross loads listed at sea level to 6,000 feet msl. Variations can be expected for change in load and/or density altitude.

★Table IV.1. *Approximate Airspeed and Power Settings —Rotary Wing Aircraft (UH-1H)*

Aircraft	Maneuver	Airspeed (knots)	Torque psi	rpm
UH-1H IROQUOIS (7,400 lbs) (Gross)	Takeoff	-----	*5	6,600
	Climb (500) fpm)	80	26	6,600
	Normal cruise	90	22	6,600
	High cruise	100	24	6,600
	Slow cruise	80	20	6,600
	Descent (500 fpm)	90	17	6,600

*Plus hovering power.

Note. All of above settings are approximate and are based only on gross loads listed at sea level to 6,000 feet msl. Variations can be expected for change in load and/or density altitude.

★5-14. Instrument Takeoff

a. The attitude indicator should be adjusted by setting the miniature aircraft as appropriate for the aircraft being flown (UH-1B and TH-13T—one bar width above horizon bar (fig 5-8); UH-1D/H and CH-47B/C—on the horizon bar). After the aircraft is alined with the runway or takeoff pad, to prevent forward movement of helicopters equipped with wheel-type landing gear, the parking brakes should be set or the toe brakes applied. If the parking brake is used, it must be unlocked after the takeoff has been completed (fig. 5-9). Sufficient friction should be applied to the collective pitch control to minimize over-controlling and to prevent collective pitch creeping. However, the application of excessive friction should be avoided in order to limit pitch control movement.

★*b.* After a recheck of all instruments to determine if they are operating properly, the takeoff (fig. 5-9) is started by making a predetermined power setting (more than is necessary for hovering but not exceeding maximum allowable power—normally 5 inches manifold pressure for reciprocating engines, or equivalent torque pressure for turbine engines). Power must be added smoothly and steadily to gain airspeed and altitude simultaneously and to prevent settling to the ground. As power is applied and the helicopter becomes airborne, pedals are used to maintain the desired heading. At the same time, forward cyclic control is applied to start the acceleration to climbing airspeed. In the initial acceleration, the attitude of the aircraft, as read from the attitude indicator, should be two bar widths below the horizon. As airspeed increases to the appropriate climb airspeed, the nose of the aircraft is gradually adjusted to the climb flight attitude. As climbing airspeed is reached, power is reduced to the climbing power setting, and transition to fully coordinated flight can be effected.

★*c.* During the initial climb-out, minor corrections to heading should be made with *pedals only* until sufficient airspeed is attained to transition to coordinated flight. A rapid cross-check must be started at the time the aircraft leaves the ground and should include all available instruments.

d. Errors common in the instrument takeoff include—

(1) Failure to maintain heading.

(2) Overcontrolling pedals.

(3) Failure to use required power.

(4) Failure to adjust pitch attitude as climbing airspeed is reached.

(5) Failure to cross-check all available instruments.

★(6) Overcontrolling pitch attitude.

★5-15. Straight Climb

a. The straight climb (fig. 5-10) can be entered from a normal cruise.

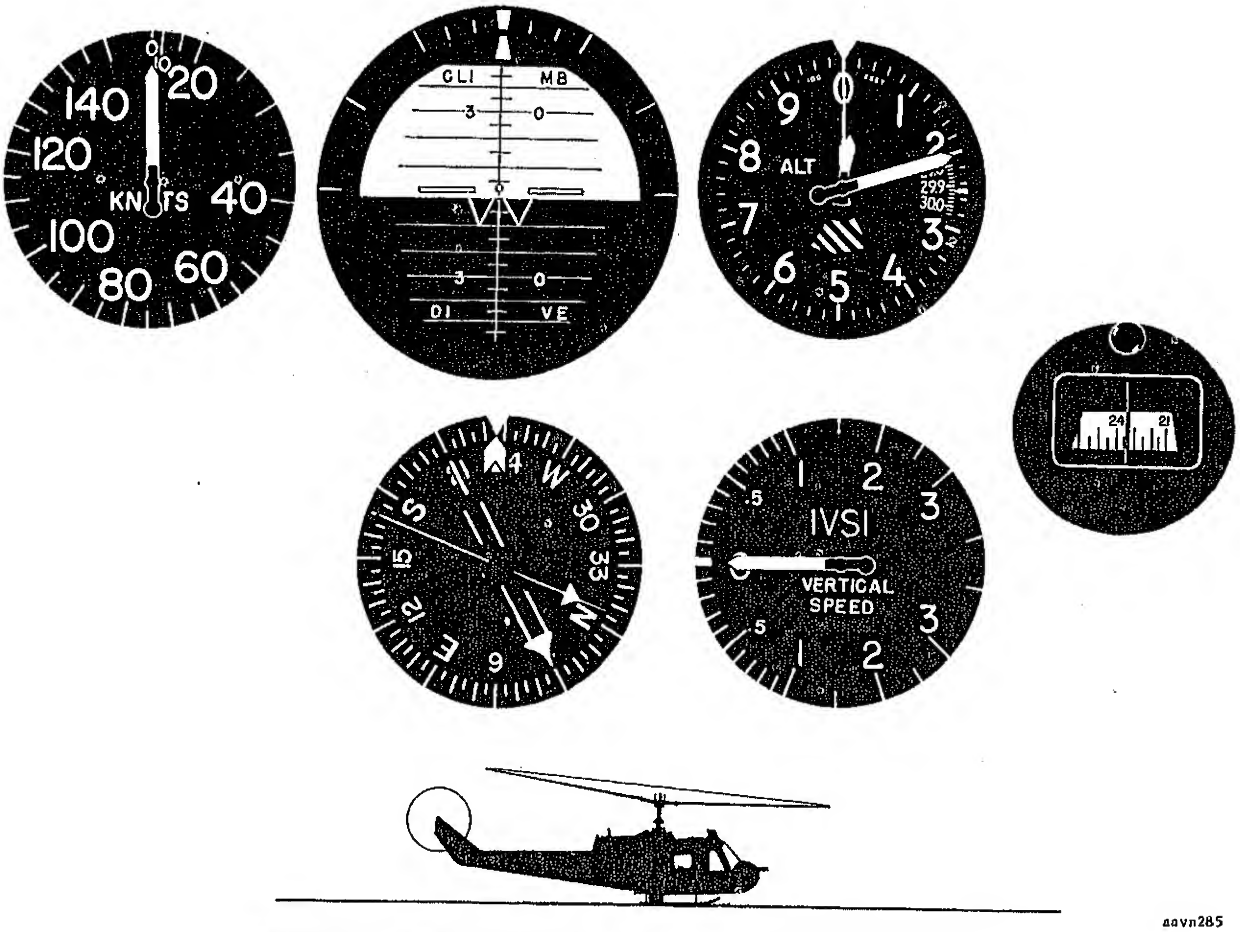
★Table VII. *Approximate Airspeeds and Power Settings—Rotary Wing Aircraft (CH-47B/C).*

Aircraft	Maneuver	Airspeed (knots)	Speed Trim	*Torque	Rotor rpm
CH-47B/C Chinook	Slow flight	70	See note 1	See note 1	See note 2
	Low cruise	100			
	Normal cruise	120			
	High cruise	140			
	Climbs	100			
	Descents	100			

*For change in vertical speed rate — 10 torque lbs per engine for 100 fpm change in vertical speed rate.

Note 1. No aircraft should be scheduled for instrument flight without an operational longitudinal cyclic speed trim programmed in the automatic mode.

Note 2. Due to the wide variation capability of airspeed versus gross weight, density altitude and rotor rpm setting will vary as will power requirements for each condition of flight. It will be necessary for the operator to consult the TM 55-1520-227-10 and appropriate CL for each condition of flight power requirements.



★*Figure 5-8. Instrument settings before takeoff (UH-1B, TH-13T).*

b. To enter a climb from normal cruise, power is increased to the setting which will produce a 500 fpm rate of climb. As power is increased, a correction for trim is made with pedals. If cruise and climb airspeeds are the same, there will be no apparent change of attitude, as read from the attitude indicator. If the amount of power applied does not produce the desired rate, minor adjustments should be made. As a rule of thumb, a change of 1 inch of manifold pressure or 1 torque pound will change the rate of climb 100 fpm (except for the CH-47). See table VII.

c. During climb, the heading, attitude, and airspeed are maintained with cyclic control. Rate of climb is controlled with power. Trim is maintained with pedals. Although the amount of lead varies with the aircraft and individual technique, a lead of approximately 40 feet should be used to level off at a desired altitude.

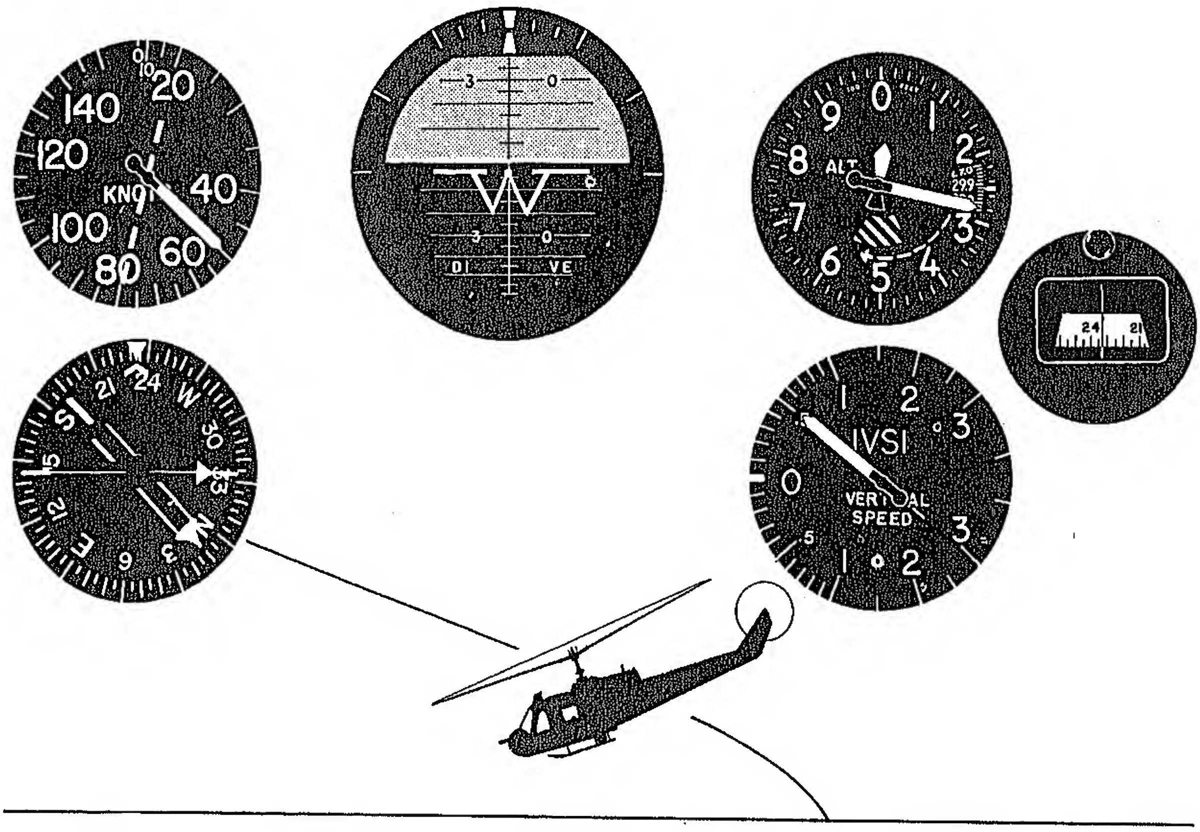
d. To level off at normal cruise, the cyclic is adjusted to establish the desired attitude with reference to the attitude indicator. Power is adjusted to maintain normal cruise airspeed.

e. Errors common in straight climbs include—

(1) Improper use of power.
(2) Overcontrolling pitch attitude.
(3) Failure to maintain heading.
(4) Failure to level off at the desired altitude.
(5) Failure to maintain adequate cross-check.

5-16. Straight and Level Flight

a. Exact straight and level flight is possible only under ideal conditions, which rarely exist. Turbulence may cause changes in the helicopter's attitude, altitude, and heading. In every flight attitude, the forces acting on the helicopter have a definite relationship. These forces (lift, weight, drag, and thrust) must be in balance for straight and level, unaccelerated flight. When an instrument indicates a need for an adjustment to maintain a given performance, other instruments will reflect the amount and direction in which the adjustment should be made. For example, if the airspeed indicator shows a decrease in airspeed, the manifold or torque pressure and/or altimeter will indicate the adjustment to be made in power and/or altitude. When altitude, airspeed, and level



★*Figure 5-9. (Superseded) Flight instruments during takeoff.*

flight are being maintained, the miniature airplane of the attitude indicator should be adjusted to reflect the level flight attitude; thereafter, any deviation in attitude can be read directly from the attitude indicator (fig. 5-11). Since the miniature aircraft is set for level flight at normal cruise, it will be seen as an approximate one-bar, above-the-horizon indication when the aircraft is in level flight at slow cruise. Corrections for attitude should be made when any deviation is observed.

★*b.* Any deviation from the desired heading will be shown on the heading indicator. Immediate and smooth application of cyclic control should be initiated to return the aircraft to the desired heading. The sooner a need for a correction is observed, the smaller the amount of correction needed. For deviations of 20° or more, a standard rate turn should be used. For deviations of less than 20°, a half-standard rate turn should be sufficient. Any time an instrument indicates a change in attitude, necessary adjustment should be made. Then, instead of watching that particular instrument to see the effects of the adjustment, the cross-check is continued before finally returning to the original instrument. In this way, the entire panel will reflect the total effect of the adjustment. A helicopter does not remain long in any given attitude; therefore, by the time a cross-check has been completed and the necessary adjustments have been made, another cross-check must be initiated.

c. During straight and level flight, heading and altitude are maintained with cyclic control; airspeed with power; trim with pedals. Power is used to adjust minor variations of altitude only if the desired altitude cannot be maintained by varying pitch attitude without exceeding ±10 knots airspeed.

d. Errors common in straight and level flight include—

(1) Failure to maintain heading.

(2) Failure to maintain altitude.

(3) Failure to cross-check all available instruments.

★(4) Overcontrolling power and attitude.

5-17. Straight Descents

★*a.* Straight descents can be entered from either normal or slow cruise. To enter a descent (fig. 5-12), power is reduced to the setting which will result in the desired rate of descent. To maintain trim as power is reduced, a correction for

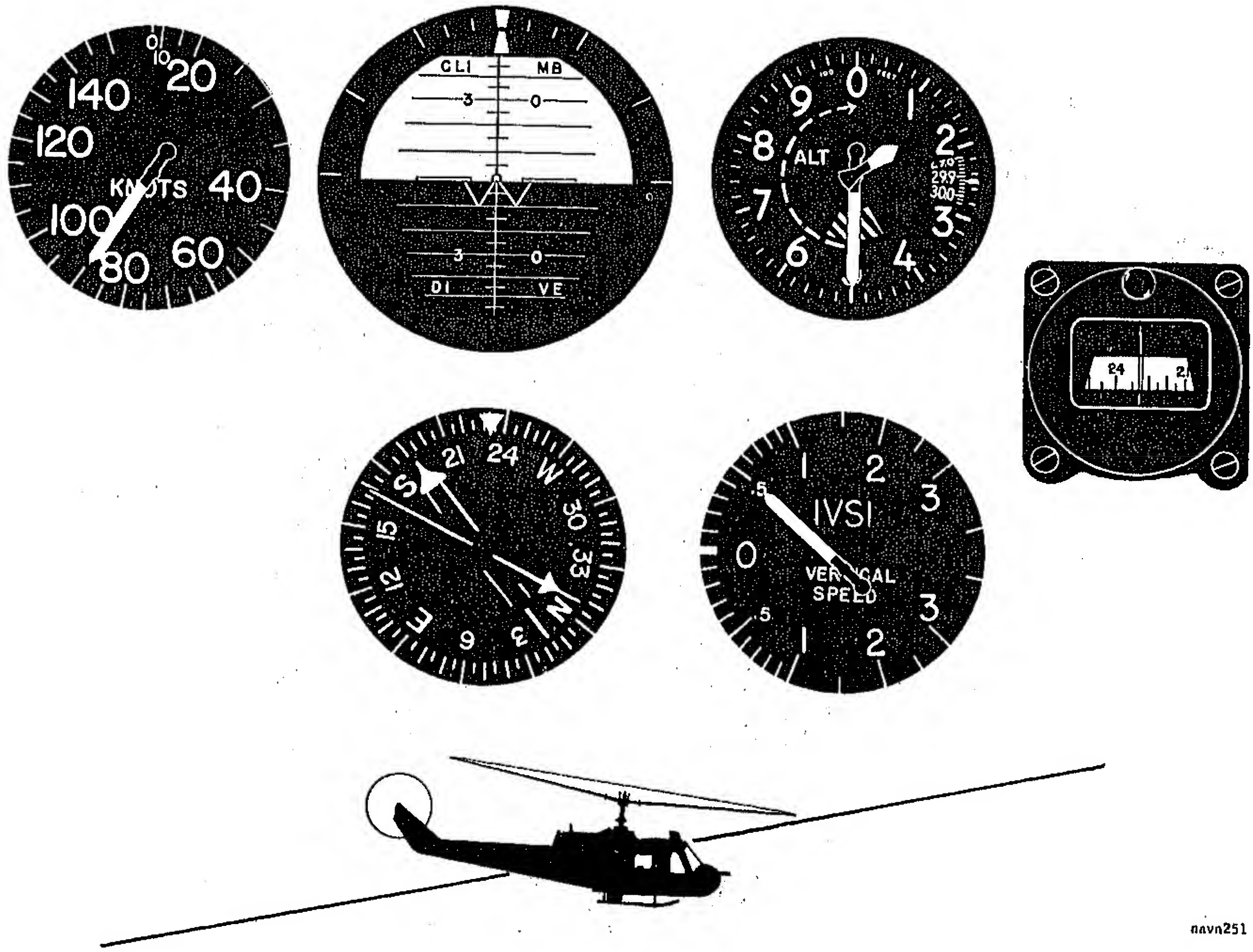


Figure 5-10. Straight climb.

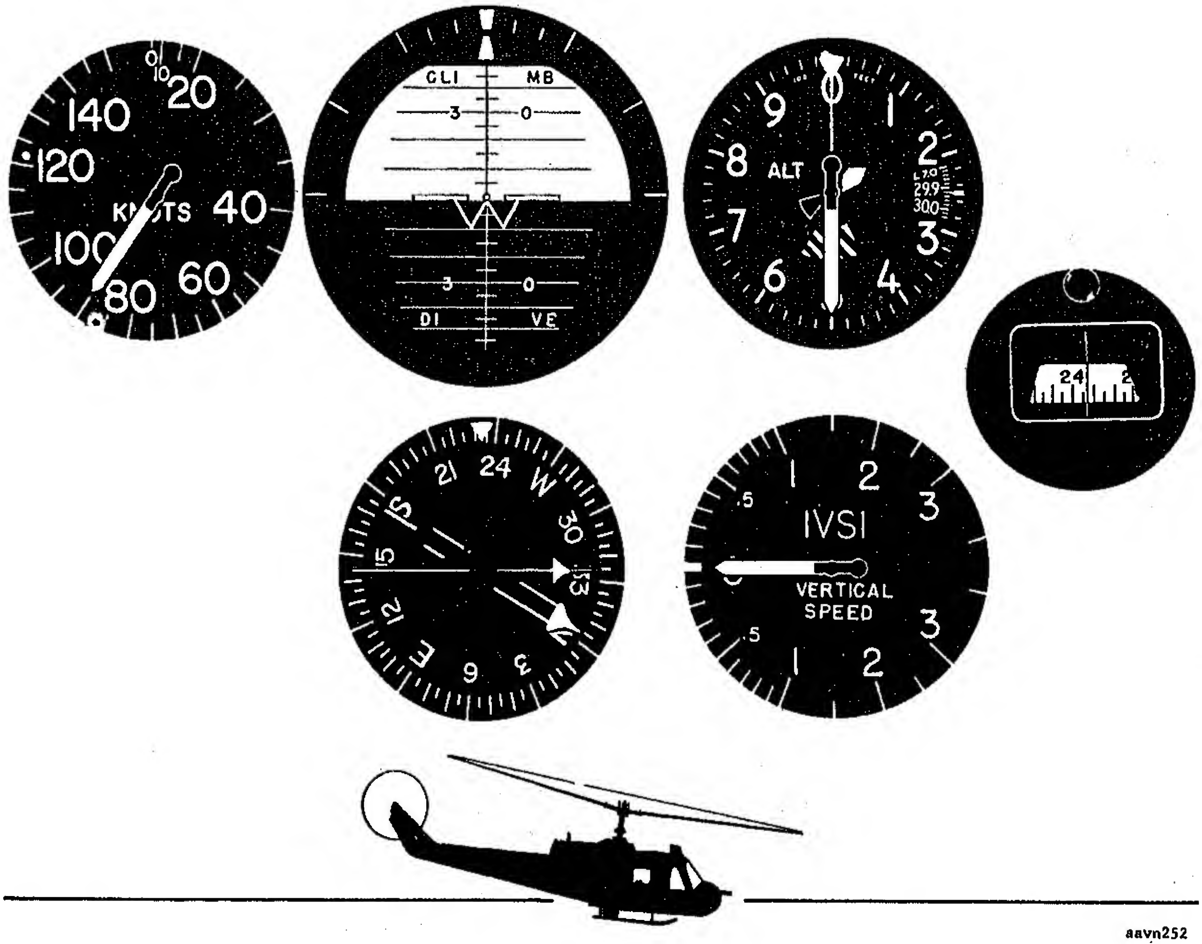


Figure 5-11. Straight and level flight.

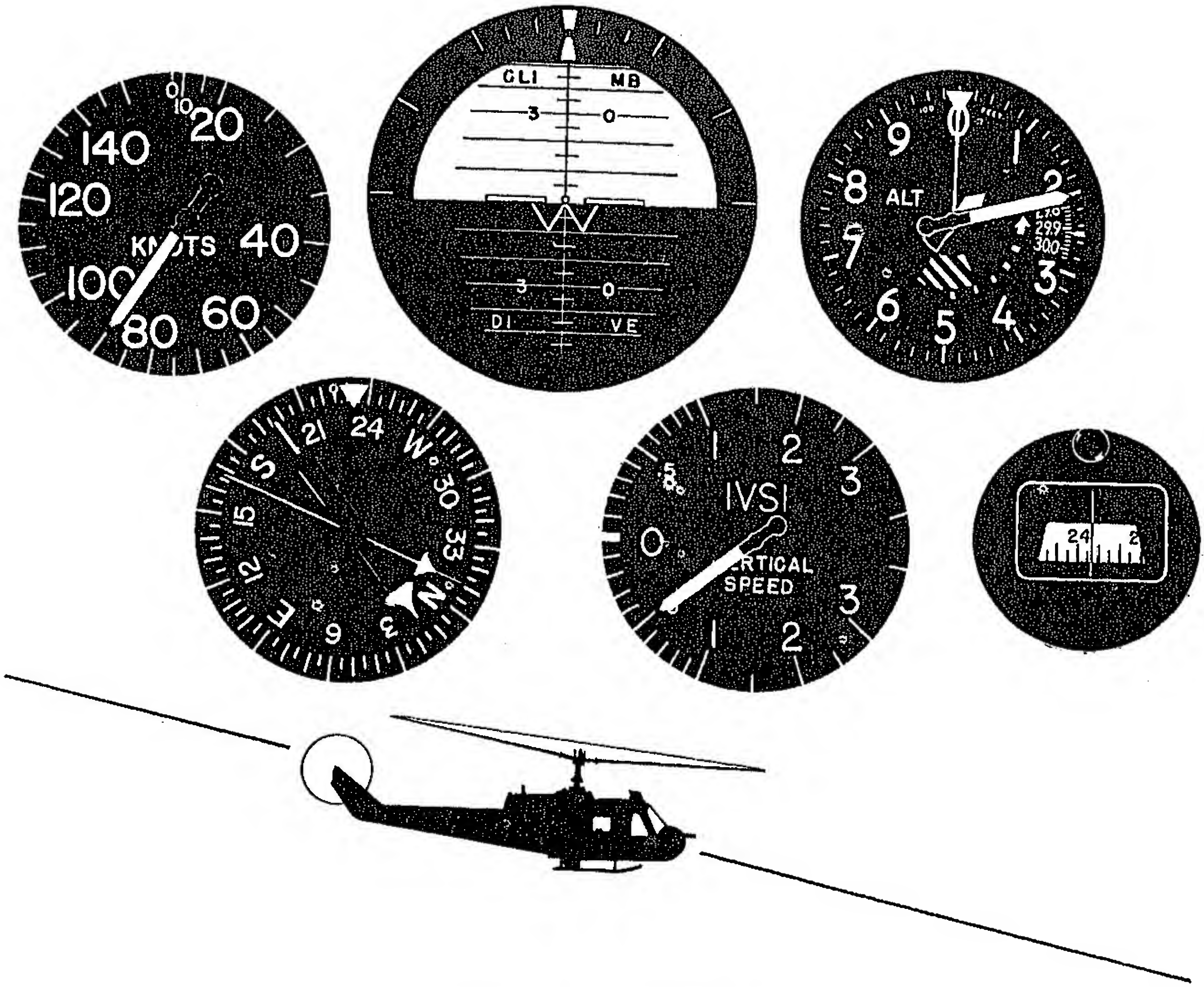


Figure 5-12. Straight descent.

torque is made with pedals. If the initial power reduction does not produce the desired rate of descent, additional adjustment should be made using the rule of thumb described in paragraph 5-15*b*.

★*b*. During descent, the heading, attitude, and airspeed are maintained with cyclic control. Rate of descent is controlled with power. Trim is maintained with pedals. To level off from the descent, power is applied prior to reaching the desired altitude. This will check the downward movement in sufficient time to prevent going below the desired altitude. The amount of lead depends on the weight of the aircraft and the rate of descent. For a 500 fpm rate of descent, the lead is normally 40 feet.

★*c*. When the proper altitude for starting the level off is reached, power is applied to the predetermined power setting and the vertical speed is checked to determine if level flight has been established.

d. Errors common in straight descents include—

(1) Failure to maintain heading.

(2) Failure to establish desired rate of descent.

(3) Failure to maintain proper trim.

(4) Failure to level off at desired altitude.

(5) Overcontrolling pitch attitude.

5-18. Turns—General

The angle of bank necessary to produce a standard rate turn is determined by the true airspeed of the aircraft. At an airspeed of 70 to 90 knots, the angle of the bank of the standard rate turn

is approximately 12° to 15°, as read from the attitude indicator. The number of degrees to be turned governs the amount of bank to be used. A change in heading of 20° or more requires a standard rate turn (3° per second) and is shown as a 2-needle deflection on the 4-minute turn-and-slip indicator. For changes of less than 20°, one-half standard rate is sufficient, and is shown as a 1-needle deflection.

5-19. Level Turns

★*a.* The level turn may be performed as a full panel or emergency panel maneuver. To enter a turn, a movement of the cyclic control is applied in the direction of the desired turn (fig. 5-13). The roll-in should be smooth and steady and should take approximately 4 to 6 seconds. The initial bank is started with reference to the attitude indicator. When the desired angle of bank and rate of turn have been attained, control pressure should be relaxed to prevent overbanking. To recover to straight and level flight, coordinated movement of the cyclic control is applied in a direction opposite to the established turn. The rate of rollout should be the same as the rate of roll-in. Straight and level flight should be established with reference to all available instruments.

b. Errors common in level turns include—

(1) Failure to maintain constant rate of turn.

(2) Failure to maintain altitude.

★(3) Deleted.

(4) Varying rate of roll-in and rollout.

5-20. Turns to Headings (Gyro)

★*a.* A turn to a gyro heading (fig. 5-14) consists of a level turn to a specific heading as read from the heading indicator, and is performed at normal cruise. Turns to specified headings should be made in the shortest direction. The turn is entered and maintained as described in the level turn maneuver. Since the aircraft will continue to turn as long as the bank is held, the rollout must be started before reaching the desired heading. The amount of lead used to rollout on a desired heading should be equal to one-half the angle of bank. The rollout on a gyro heading is performed in the same manner as the rollout of the level turn. When the heading for starting the rollout is reached, cyclic control is applied in the direction opposite the turn.

b. Errors common in turns to headings include—

(1) Failure to use proper lead in rollout of the turn.

(2) Failure to maintain altitude.

(3) Failure to turn in the shortest direction.

★(4) Failure to recover from the turn with the proper heading and altitude.

★(5) Overcontrolling pitch and bank attitudes.

5-21. Compass Turns

★*a.* The inherent characteristics of the compass must be understood to be able to turn the aircraft to a magnetic heading and maintain it (fig. 5-15 and 5-15.1).

★*b.* With a standard angle of bank, the amount of lead or lag to be used when turning to headings of north and south varies with, and is approximately equal to, the latitude of the locality over which the turn is made. This lead or lag is at a minimum over the Equator and increases as the latitude increases, reaching its maximum at the polar regions. The angle of bank must be accurately held to attain success in turns to magnetic compass headings. The compass reading is reliable only when the aircraft is in a wings-level and constant-pitch attitude at a constant airspeed and in coordinated flight.

★*c.* In the northern hemisphere, when turning to a heading of north, the rollout lead must be the number of degrees equal to the latitude plus one-half the angle of bank used in the turn. *For example*, during a left turn to a heading of north in a locality where the latitude is 30° and the angle of bank is 12°, the rollout should be started when the magnetic compass reads 36° (30° plus one-half of 12°). To turn to a heading of south, the aircraft must be turned past south the number of degrees equal to the latitude minus one-half the angle of bank used in the turn. For example, when turning to the right to a heading of south, the rollout is started when the magnetic compass reads 204° (180° plus 30° minus 6°). When turning to a heading of east or west from a northerly heading, the rollout is started approximately 10° before the heading is reached. When turning to a heading of east or west from a southerly heading, the rollout is started approximately 5° before the heading is reached. When turning to other than cardinal headings, the lead or lag must be interpolated. South of the Equator, lead and lag are reversed.

★*d.* Errors common in compass turns include—

Figure 5–13. Level turns.

(1) Failure to use proper lead in rollout of ıe turn.

(2) Failure to maintain a constant angle of ınk.

(3) Failure to maintain attitude control.

(4) Failure to maintain coordinated flight.

(5) Improper computation of rollout point.

(6) Failure to maintain constant airspeed.

5–22. Steep Turns

★*a.* Any turn greater than standard rate is considered a steep turn (fig. 5–16); however, for practice, a 4-minute turn needle should indicate a 3-needle width turn. A steep turn is seldom necessary or advisable in instrument weather, but it is a good test of the individual's ability to react quickly and smoothly to changes in aircraft attitude. The technique of entry and recovery are the

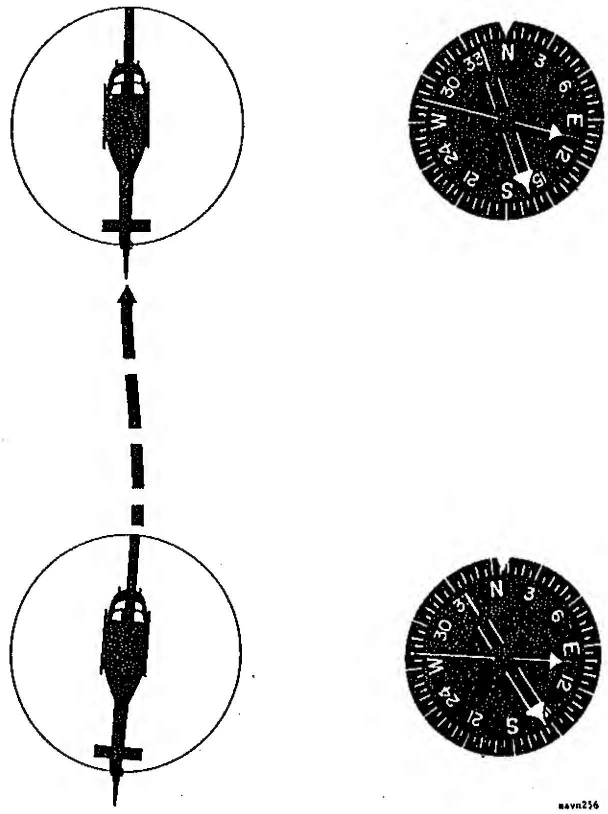


Figure 5-14. Turns to headings (gyro).

same as for any turn maneuver. Rate of turn and attitude are maintained with cyclic control; airspeed and altitude are maintained with power.

b. Errors common in steep turns include—

(1) Failure to maintain altitude.

(2) Failure to hold a constant rate of turn.

★(3) Deleted.

(4) Failure to maintain airspeed.

5-23. Timed Turns

a. In a timed turn, the heading of the aircraft is changed a definite number of degrees with reference to the turn-and-slip indicator and the clock. The timed turn is performed at normal cruise with the heading and attitude indicators covered. To perform accurate timed turns, the needle of the turn-and-slip indicator must be calibrated.

b. To calibrate the turn needle, the approximate angle of bank for a standard rate turn is established with reference to the attitude indicator. Necessary changes are made to produce an indication of a standard rate turn with reference to the turn needle. Unless oscillations of the turn needle are of equal distance on either side of the standard rate position, (averaged out) error result in the rate of turn. After establishin rate of turn, the position of the second hand the heading are noted. The rate of turn is tained until a predetermined time has elaps and the heading is noted again.

c. Exact timing is very important. If the needle is in calibration, a standard rate of for 10 seconds will produce a change in hea of 30°. Any deviation is corrected by char the position of the turn needle so that a tu 3° per second results. When the needle is pro calibrated, the position is carefully noted and during all standard rate turns.

d. Prior to starting the turn, the time n sary to turn to the new magnetic heading be computed. To compute the time in sec the angular difference (shortest direction) tween the present heading and the new hea is divided by three.

e. The techniques of entry and contro the timed turn are the same as for the turn (para. 5-19). The position of the se hand of the clock must be noted when the is started (fig. 5-17). For ease in timing,

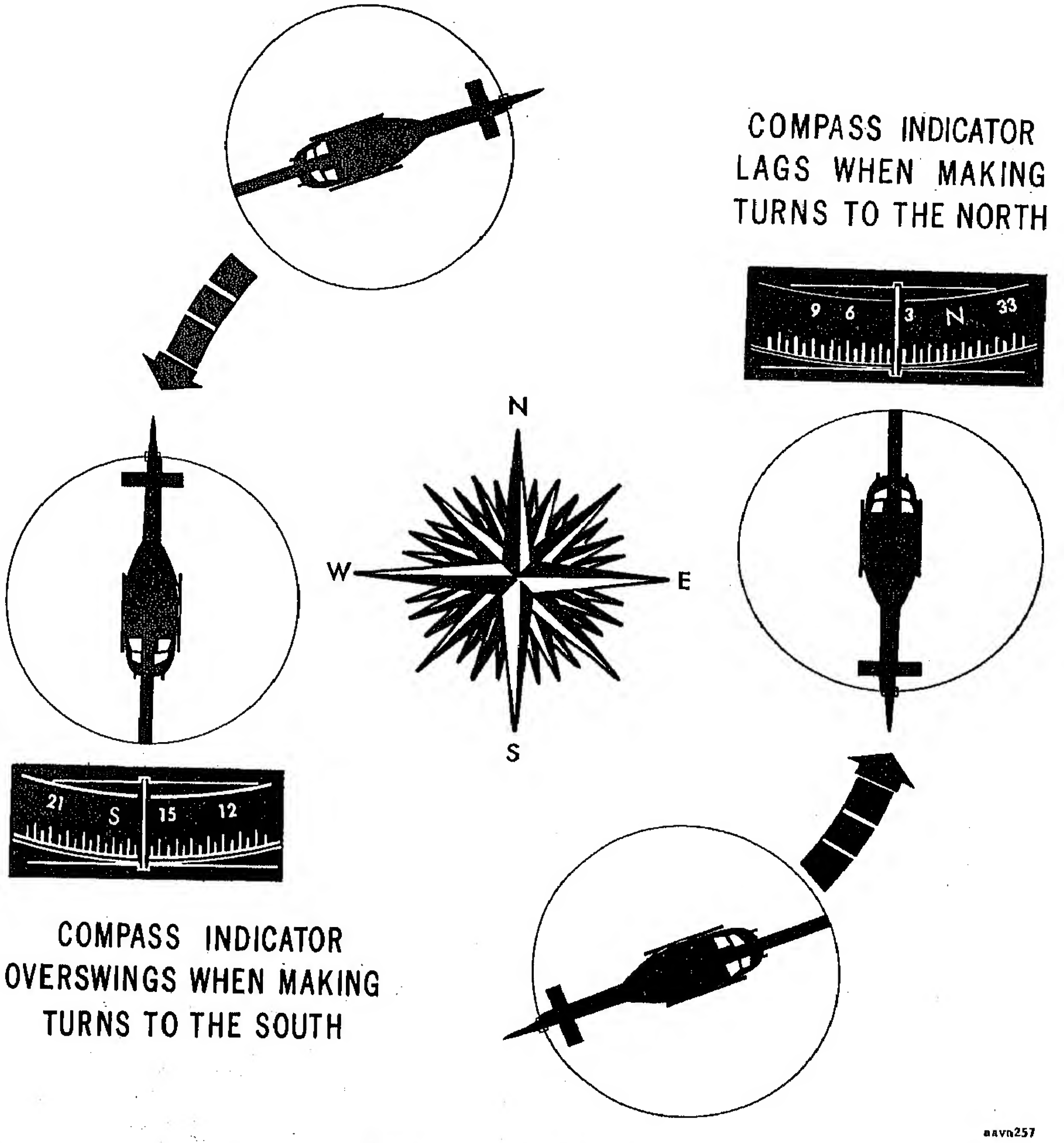


Figure 5-15. Compass turns.

best to start the time when the second hand passes the 12-, 3-, 6-, or 9-o'clock position. The standard rate of turn must be maintained until the predetermined time has elapsed, then the rollout is started. The rate of rollout is the same as the rate of roll-in. After straight and level flight is established, the compass should reflect the desired heading.

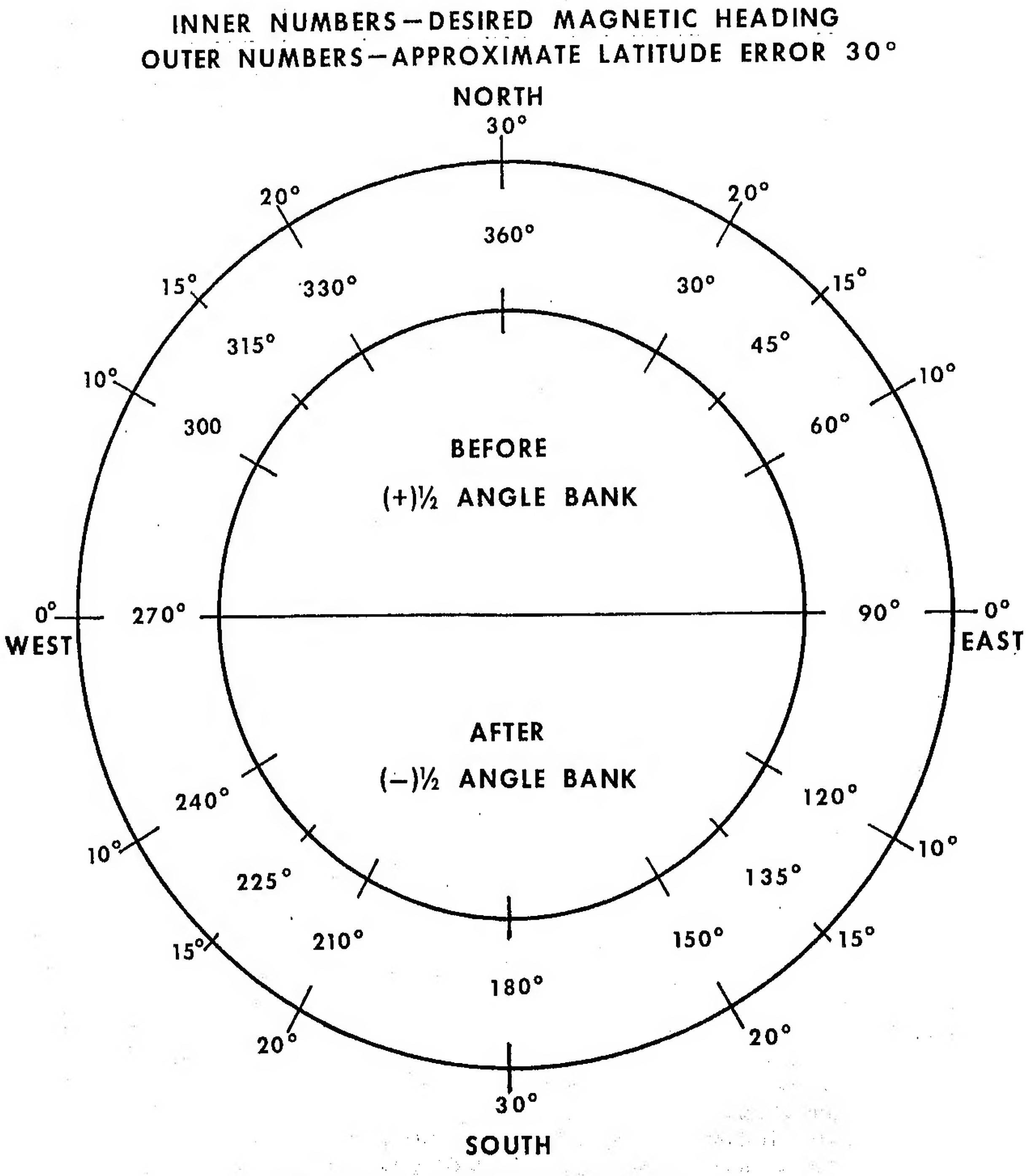
f. Errors common in timed turns include—

(1) Failure to maintain a standard rate turn

(2) Failure to compute turning time properly.

(3) Failure to use the same rate of roll-in and rollout.

(4) Failure to maintain altitude.



★*Figure 5–15.1. Compass turn maneuver procedure.*

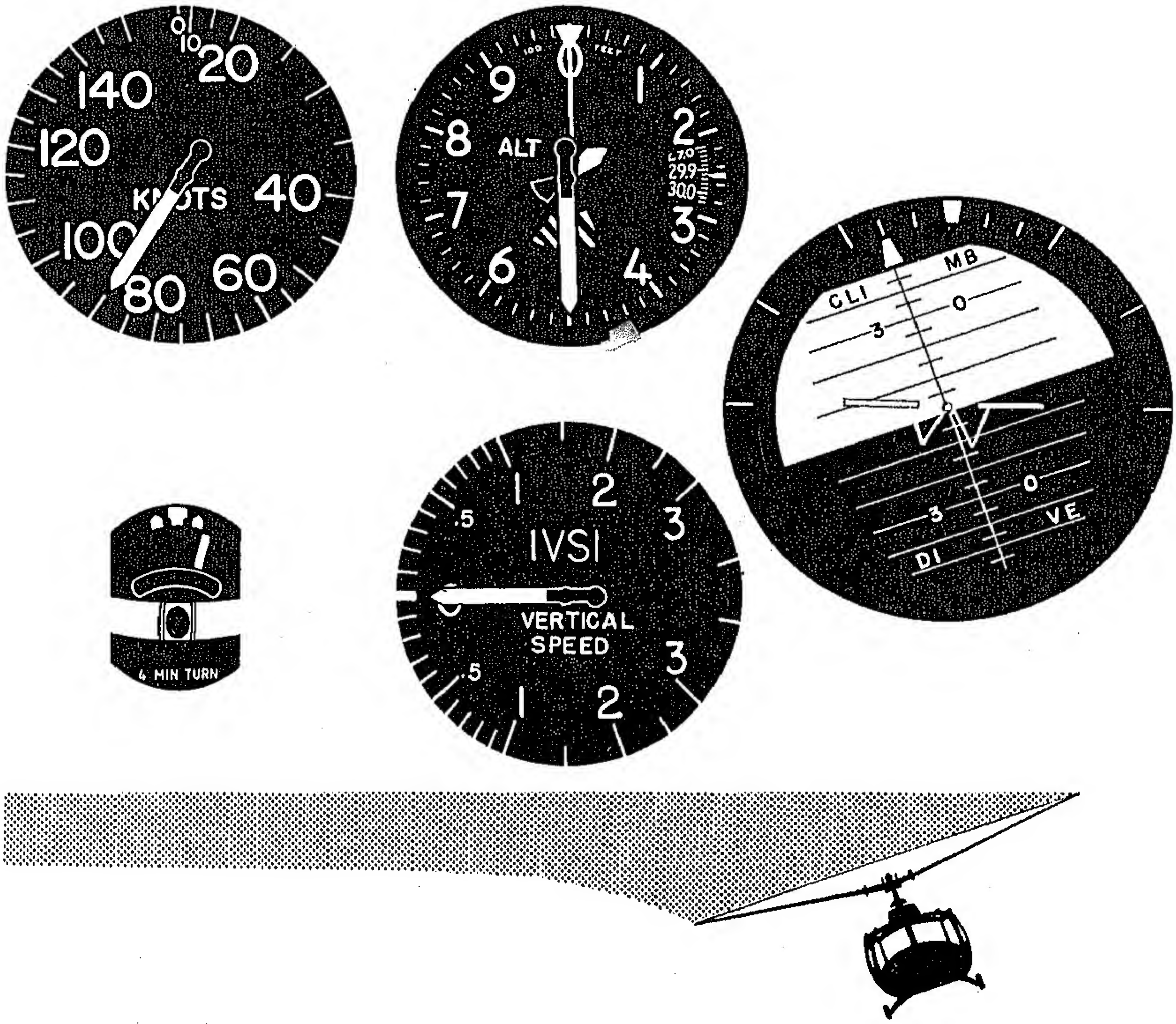


Figure 5-16. Steep turns.

5-24. Climbing Turns

a. A climbing turn (fig. 5-18) is a combination of a climb and a turn, and consists of a climb of 500 feet during a turn of 180° in 60 seconds. In this maneuver the rate of climb and the rate of turn are both checked against time. The climbing turn is generally performed at normal cruise and requires a very rapid cross-check for precise execution.

★*b.* The climbing turn (fig. 5-18) is started as the second hand of the clock passes the 12-, 3-, 6-, or 9-o'clock position. As the power is applied to the predetermined setting, torque corrections should be made with pedals to maintain trim. The initial bank should be established with reference to the attitude indicator. To maintain the rate of turn, minor bank corrections are made with reference to the turn-and-slip indicator. During the climbing turn, the rate of turn and airspeed are maintained with cyclic control; the rate of climb is maintained with power, and trim with pedals. Power is used to adjust the rate of climb only if the desired airspeed is exceeded by ±5 knots. (The ±5 knots is used for minor pitch correction during climbs and descents.) After 30 seconds, the aircraft will have turned approximately 90° and climbed approximately 250 feet. If the instruments indicate other than the desired readings, the rate of climb and/or turn should be adjusted as necessary. A further check can be made at the expiration of 45 seconds. Ad-

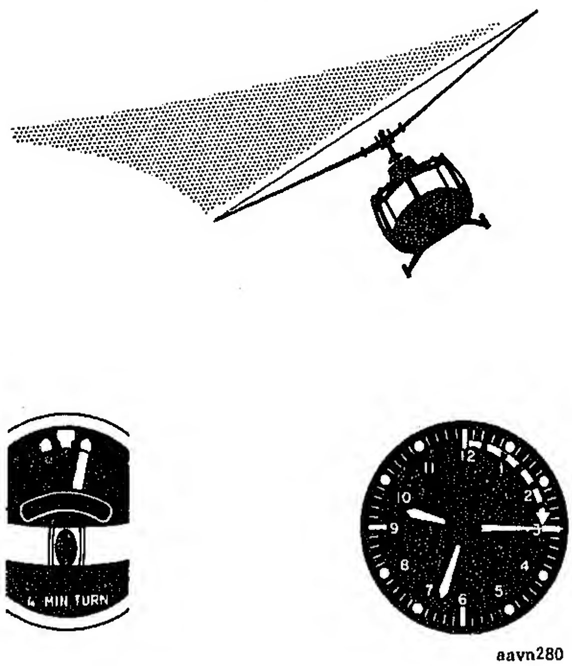


Figure 5-17. Timed turns.

justments in the rate of climb and/or turn should again be made if necessary. Normally the recovery should be started as the second hand reaches the original starting position (60 seconds). However, regardless of the time factor, a recovery should be made when the desired heading and altitude have been reached.

c. Errors common in climbing turns include—

(1) Failure to detect a need for a change in rate of turn and/or climb.

(2) Improper use of power.

(3) Improper use of pedals.

(4) Failure to recover from the turn at the proper heading and altitude.

(5) Overcontrolling pitch and bank attitudes.

★5-25. Descending Turns

a. A descending turn (fig. 5-19) is a combination of a descent and a turn, and consists of a descent of 500 feet during a turn of 180° in 60 seconds. In this maneuver the rate of descent and the rate of turn are both checked against time. The descending turn is generally performed at normal cruise airspeed and requires a very rapid cross-check for precise execution.

b. The descending turn (fig. 5-19) is started as the second hand of the clock passes the 12-, 3-, 6-, or 9-o'clock position. As the power is reduced to the predetermined setting, torque correction should be made with the pedals to maintain trim. The initial bank should be established with reference to the attitude indicator. To maintain the rate of turn, minor bank corrections are made with reference to the turn-and-slip indicator. During the descending turn, the rate of turn and airspeed are maintained with cyclic control; rate of descent, with power; and trim, with pedals. Power is used to adjust the rate of descent only if the desired airspeed is exceeded by ±5 knots. (The ±5 knots is used for minor pitch correction during climbs and descents.) After 30 seconds, the aircraft will have turned approximately 90° and descended approximately 250 feet. If the instruments indicate other than the desired readings, the rate of descent and/or turn should be adjusted as necessary. A further check can be made at the expiration of 45 seconds. Adjustments in the rate of descent and/or turn should again be made if necessary. Normally the recovery should be started as the second hand reaches the original starting position (60 seconds). However, regardless of the time factor, a recovery should be made when the desired heading and altitude have been reached.

c. Errors common in descending turns include—

(1) Failure to detect a need for a change in rate of turn or rate of descent.

(2) Improper use of power.

(3) Improper use of pedals.

(4) Failure to recover from the turn with the proper heading and altitude.

(5) Overcontrolling pitch and bank attitudes.

5-26. Unusual Attitudes and Recoveries

a. Any maneuver not required for normal instrument flight is an unusual attitude and may be caused by turbulence, vertigo, instrument failure, or carelessness in cross-checking. Due to the inherent instability of the helicopter, unusual attitudes can be extremely critical. As soon as an unusual attitude is detected, a recovery to level flight must be made as quickly as possible, with a minimum loss of altitude.

b. The recovery from an unusual attitude requires an immediate analysis of what the helicopter is doing and how to return it to normal flight as quickly as possible with a minimum loss of altitude.

c. To recover from an unusual attitude, bank and pitch attitude should be corrected and power

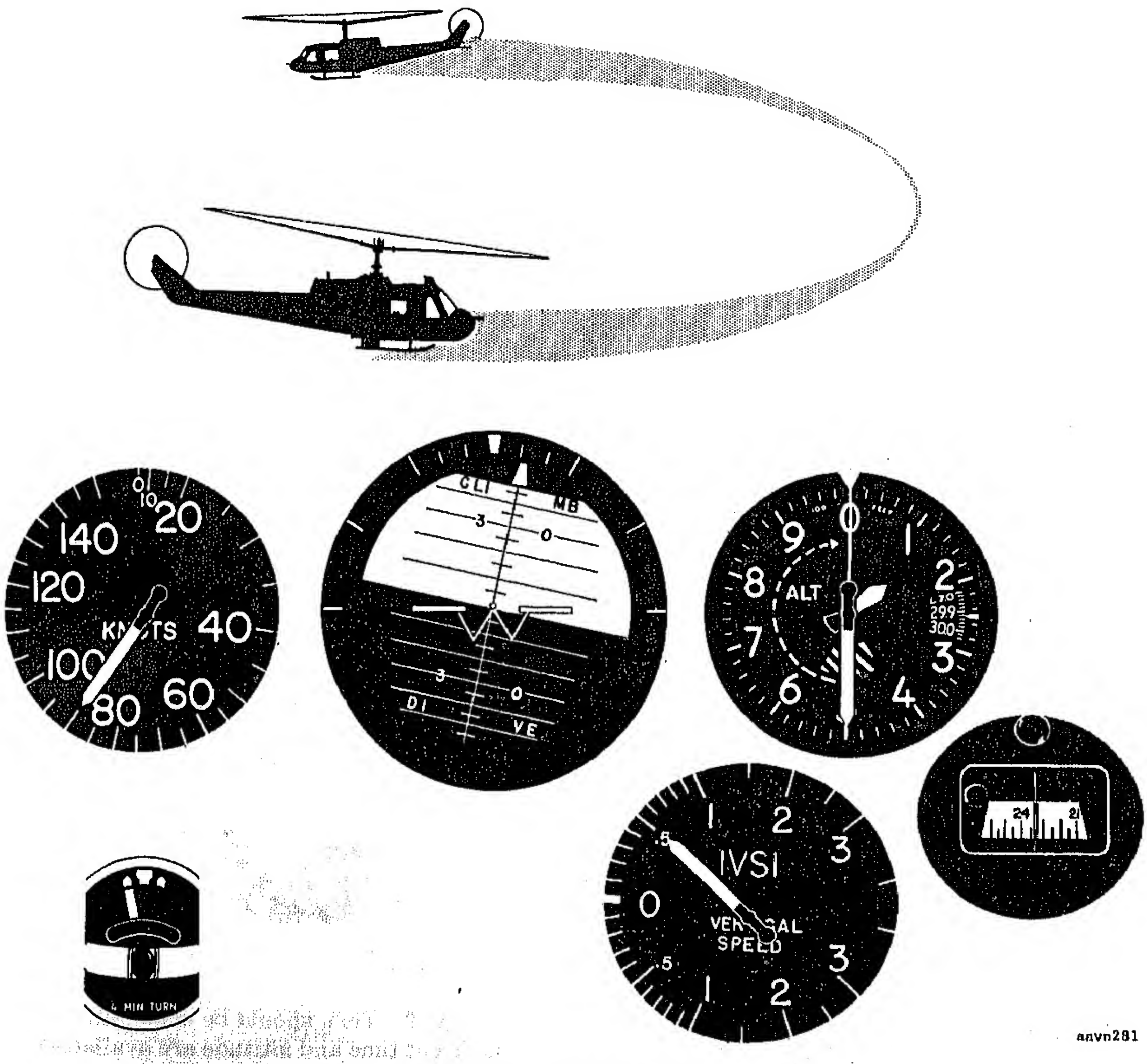


Figure 5–18. Climbing turns.

adjusted as necessary. All components are changed almost simultaneously with little lead of one over the other.

Example, if the aircraft is in a steep ascending or descending turn, bank, pitch, and power should be corrected simultaneously. The bank attitude is corrected with reference to the turn-and-slip indicator (attitude indicator if available). Pitch attitude is corrected with reference to altimeter, airspeed, vertical speed, and attitude indicator if available. Power is adjusted with reference to torquemeter, manifold pressure gage, and airspeed indicator.

d. Since the displacement of controls used in recoveries from unusual attitudes may be greater than those for normal flight, care must be taken in making adjustments as straight and level flight is approached. The instruments must be observed closely to avoid overcontrolling.

e. Errors common to recoveries from unusual attitudes include—

(1) Failure to make power correction.

(2) Failure to correct pitch attitude.

(3) Failure to correct bank attitude.

(4) Overcontrolling pitch and bank attitude.

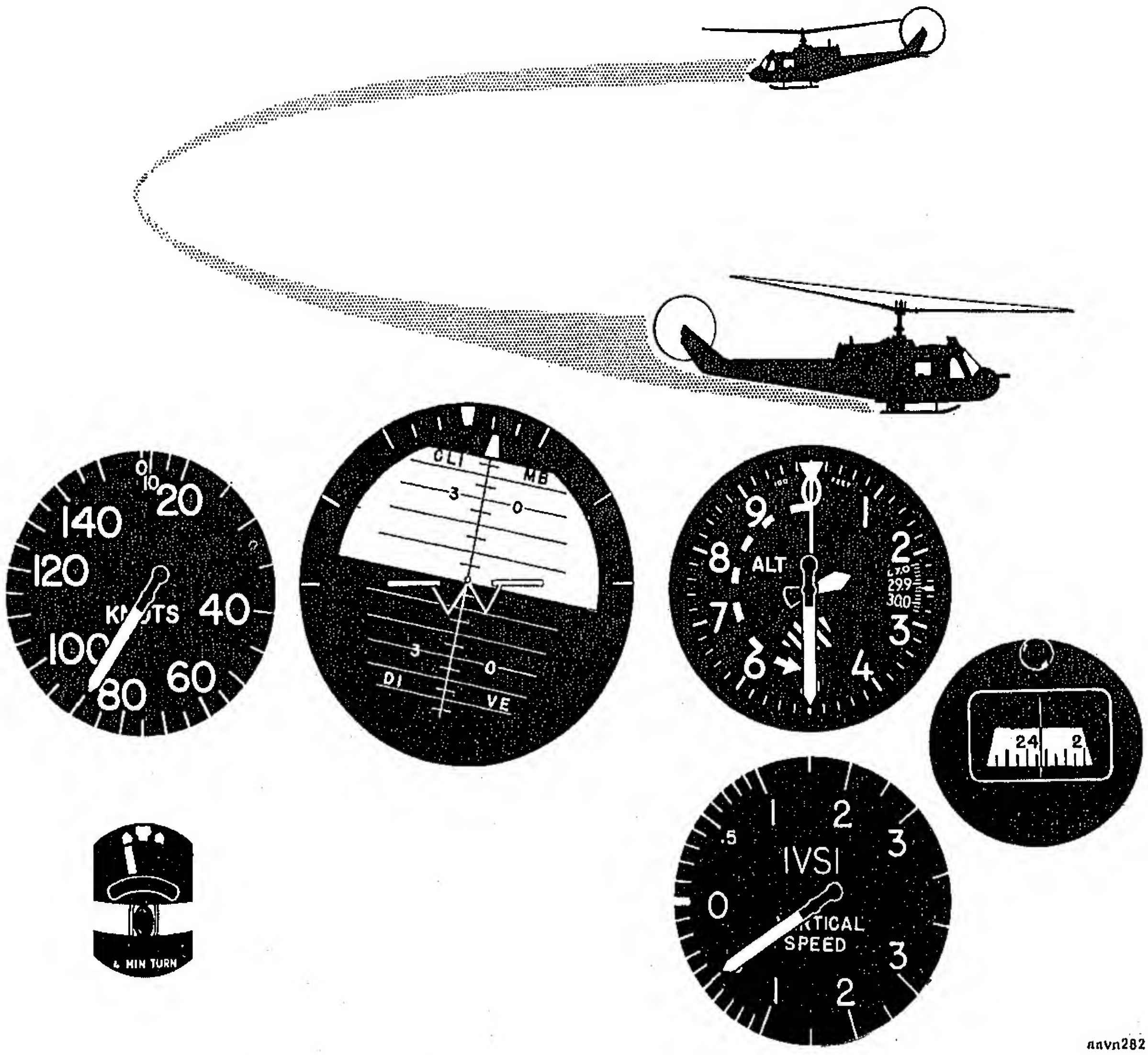


Figure 5-19. Descending turns.

(5) Excessive loss of altitude.

★(6) Overcontrolling power.

5-27. Autorotations

An autorotation is a descent without power in a helicopter. In the event of power failure or other emergencies requiring autorotation, prompt corrective action must be taken to insure positive control of the aircraft.

a. To enter autorotation—

(1) Collective pitch must be reduced smoothly to maintain safe rotor rpm, and pedals must be trimmed to assure coordinated flight. The attitude of the aircraft should be wings-level and the airspeed adjusted to the autorotative speed (approximately 80 knots for the UH-1).

★(2) Turn should be made into the wind (if sufficient time and altitude are available) by using no greater than a standard rate turn.

b. Practice autorotations must be terminated with a power recovery. Recovery is begun to stop the descent at the desired altitude. A lead of 150 to 250 feet usually will be sufficient to prevent overcontrolling during the recovery. Recovery must be accomplished by adjusting collective pitch to bring the rotor rpm within the engine rpm limits; power must be applied to join the needles; and a power adjustment must be made to the desired power setting. Pedals must be trimmed to maintain coordinated flight during power application.

c. As proficiency is gained, autorotations and

forced landings are practiced without prior warning.

d. Errors common in autorotations and corrective actions include—

(1) Skidding and slipping on entry: stress pedal trim.

(2) Improper airspeed or airspeed variation: stress constant pitch attitude.

★5-28. Accelerations and Decelerations

An acceleration or a deceleration is a proficiency maneuver that can be practiced during straight and level flight.

a. To practice this maneuver, the airspeed should be at normal cruise. Power changes should be executed in coordination with all available attitude instruments. Power changes of approximately 2 torque pounds above and below cruise torque setting will result in an approximate 10-knot change in airspeed. Changes in attitude and trim control must be made throughout the maneuver to maintain altitude and desired heading.

b. To accelerate from normal cruise to high cruise, power is increased 2 pounds of torque above that required to maintain high cruise; then as the desired airspeed is approached, power is reduced to high cruise power setting.

c. To decelerate from high cruise to low cruise, power is reduced 2 pounds of torque below that required to maintain low cruise; then as the desired airspeed is approached, power is increased to low-cruise setting.

d. To accelerate from low cruise to normal cruise, power is increased 2 pounds of torque above that required to maintain normal cruise; then as the desired airspeed is approached, power is reduced to normal cruise setting.

e. Errors common in acceleration and decelerations include—

(1) Improper use of power.

(2) Overcontrolling pitch attitude.

(3) Failure to maintain heading.

(4) Failure to maintain altitude.

(5) Overcontrolling power.

(6) Failure to maintain proper turn.

(7) Improper pedal adjustment.

5-29. Servo Failure

Servo failure is a loss in use of the control boost system and is evidenced by stiffness, feedback in controls, and the warning lights.

a. In the event of servo failure—

(1) Maintain aircraft control.

★(2) Complete emergency procedure in accordance with CL.

b. Servo failure is simulated by turning off the servo switch. To practice servo failure maneuvers—

(1) The instructor turns servos off, initially with prior warning to the individual.

★(2) Deleted.

★(3) Procedures set forth in *a* above are followed.

c. Errors common to servo failure maneuvers and corrective actions include—

(1) Failure to adjust to the recommended servo-off airspeed: emphasize appropriate airspeed and control technique.

(2) Failure to maintain desired heading and altitude: review attitude control and practice servo-off flight.

(3) Failure to reset master caution warning light: reemphasize resetting of warning light.

★(4) Failure to apply correct CL procedure.

CHAPTER 6

PROFICIENCY MANEUVERS (FIXED WING)

6–1. General

The maneuvers described in this chapter are practiced primarily to develop proficiency in power, pitch, and bank control, and to increase the aviator's speed in cross-checking.

6–2. Vertical S and S–1

a. The *vertical S* (fig. 6–1) consists of a series of climbs and descents. Throughout the maneuver, constant airspeed and heading are maintained. All climbs and descents are made at a constant rate as shown on the vertical speed indicator, and the reversing of vertical direction is made at specified altitudes. The time element is eleminated from the maneuver. The vertical S is entered as in a constant rate climb or descent (para. 5–5). During the climb or descent, pitch attitude is controlled with reference to the vertical speed indicator, and airspeed is controlled with power. The heading indicator is referred to for bank control throughout the maneuver. The change from a climb to a descent requires the same amount of lead on altitude that is used in a *level-off*. Power must be used smoothly and must be promptly adjusted to the approximate setting when pitch change is being made to the approximate descending attitude. The same control technique is used in changing from a descent to a climb. The frequency of reversing the vertical direction depends upon the type of aircraft used.

b. The climbs and descents will be at the same indicated rate as the amount of altitude to be gained or lost. Normally, in aircraft with a low rate-of-climb capability, the maneuver is accomplished by climbing 500 feet, descending 500 feet; climbing 400 feet, descending 400 feet; climbing 300 feet, descending 300 feet; and, climbing 200 feet, descending 200 feet. This completes the maneuver. High performance aircraft may accomplish the maneuver by changing altitudes of 1,000, 800, 600, and 400 feet, with corresponding rates of climb and descent. Trim control is especially important because of the constant changes in attitude and power throughout the maneuver. The frequency of these changes requires a rapid cross-check for precise control of the aircraft.

c. The *vertical S–1* (fig. 6–2) is a combination of the vertical S and standard rate turns of 360°. Each turn is started in a climb and ends in a descent. The direction of the bank is reversed after each descent.

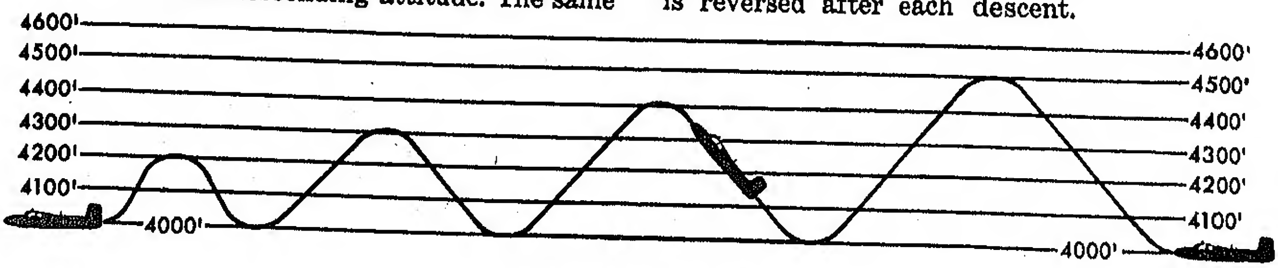


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Figure 6–1. Vertical S.

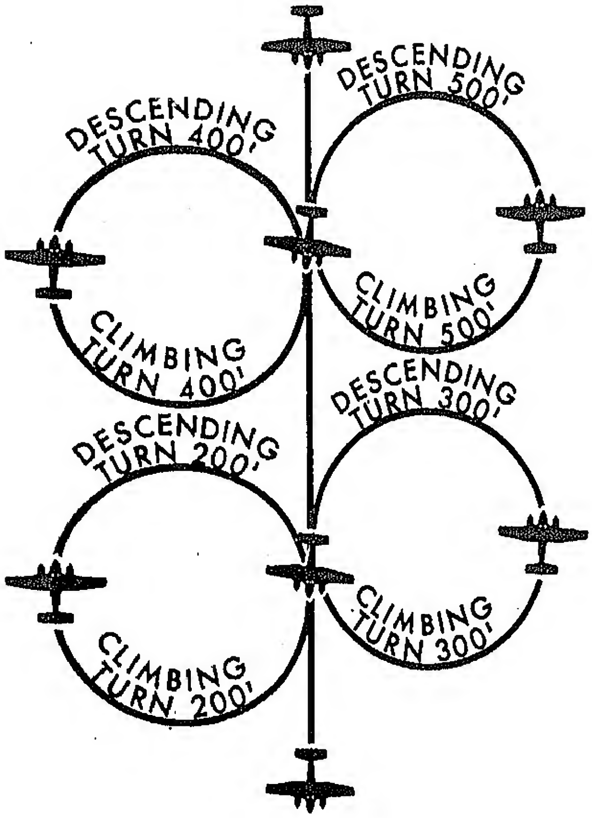

Figure 6-2. Vertical S-1.

d. Errors common to the vertical S and S-1 maneuvers include—

(1) Failure to use the airspeed indicator properly for pitch control when changing the vertical direction.

(2) Overcontrol of pitch attitude when climbing and descending (indicated by excessive movement of the vertical speed indicator).

(3) Failure to use the proper altitude lead when reversing the vertical direction.

(4) Failure to correct sufficiently for torque when power is changed.

6-3. Pattern A

Pattern A (fig. 6-3) is designed to give practice in maintaining straight and level flight and performing timed turns at definite time intervals. It is a combination of the procedures that will be used in the advanced phase of instrument training. As such, it is invaluable experience in planning, precision timing, maintaining orientation, holding, and performing procedure turn and approach.

a. Prerequisites for successful performance of pattern A are—

(1) *Proficiency in performing timed turns without the use of the attitude and heading indicators.* Timing should begin when the second hand is on the 12-o'clock (preferable) or 6-o'clock position. All legs are 2 minutes long except the first, which is 1 minute. All turns are 3°-per-second timed turns. Timing for all turns begins and ends on a cardinal point on the clock. Timing for each leg of the pattern begins at the same moment that pressure is applied on the controls to roll the aircraft out of the preceding turn, even though the aircraft is still turning and is not on the desired heading.

(2) *Understanding of the proper use of the magnetic compass and awareness of its errors.* The pattern may be started on any heading; however, initial practice should be done on cardinal headings for simplification.

(3) *Familiarity with the pattern and knowledge of the power settings for the different airspeeds used.*

b. When the aircraft is in straight flight and a few seconds have been allowed for the magnetic compass to stop oscillating, the compass heading is noted. If the aircraft is not on the correct compass heading, a correction

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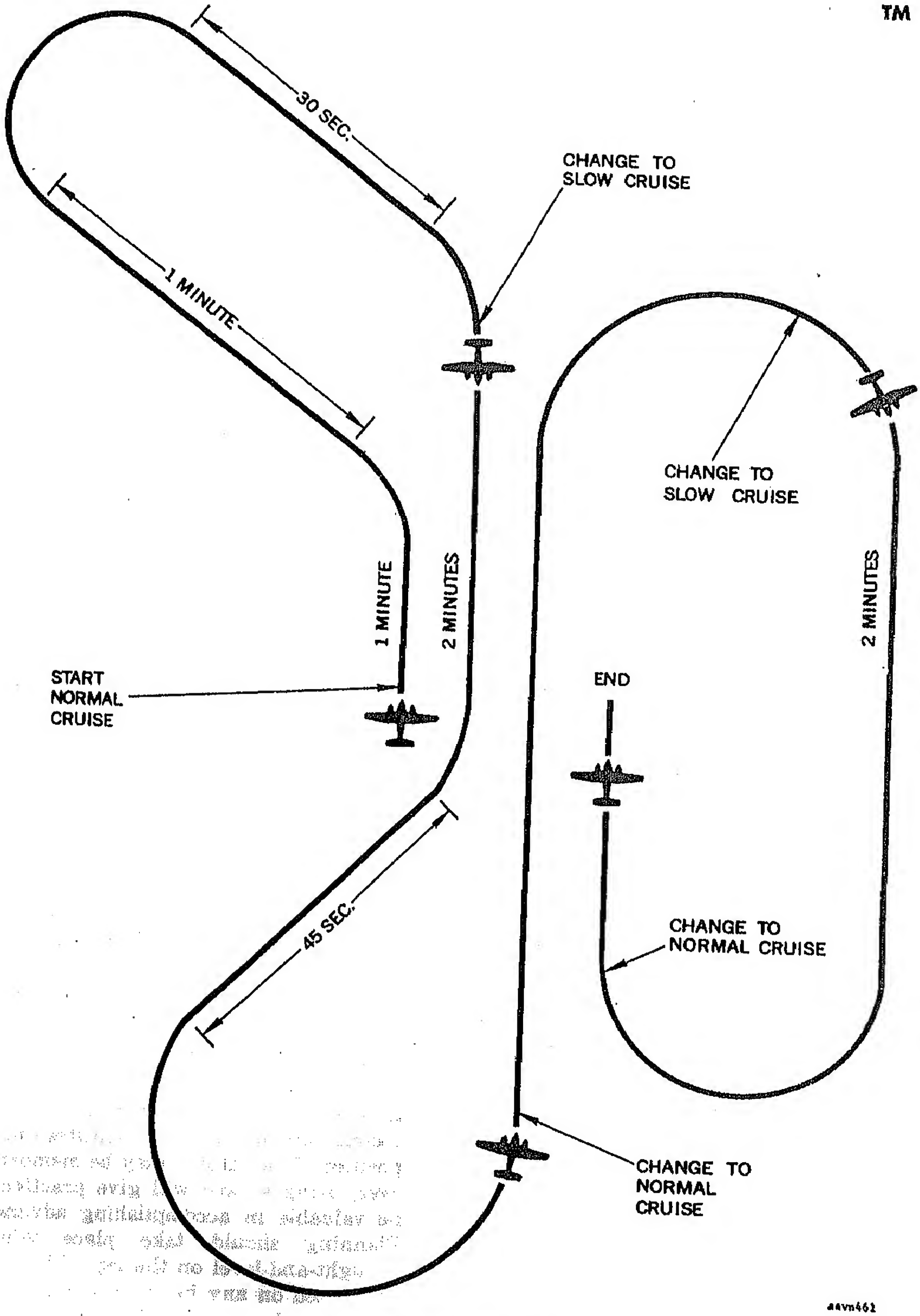

Figure 6-3. Pattern A.

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is made toward the desired heading before changing the airspeed. On headings of north and south, this correction must be a timed turn; however, in the vicinity of east and west, a shallow bank and turn directly to the heading is possible since there is no turning error on headings of east and west.

c. The airspeed should be changed immediately if a correction of heading is not required. When the turn-and-slip indicator is the only bank instrument available, it must be observed closely at all times. The magnetic compass can be used only to determine the accuracy of the heading. The altimeter is used with the vertical speed indicator to maintain precise pitch control. A rapid and efficient cross-check is required during changes of airspeed, so that corrections can be applied immediately.

d. Errors common in the pattern A maneuver include—

(1) Failure to control bank properly in turns.

(2) Failure to maintain heading and altitude.

(3) Attempting to use the compass as a bank instrument.

(4) Poor bank control during changes in airspeed.

(5) Failure to make allowances for an incorrectly calibrated turn needle during the timed turns.

6-4. Pattern B

a. Pattern B (fig. 6-4) is designed to give further practice in the procedures used during the advanced phase and to combine most of the maneuvers previously performed. It is essentially the same maneuver as pattern A with the following exceptions:

(1) All available instruments are used.

(2) The airspeed is changed during the turns.

(3) A prelanding check is completed on the fourth leg.

(4) Descents at 500 fpm are made during the maneuver.

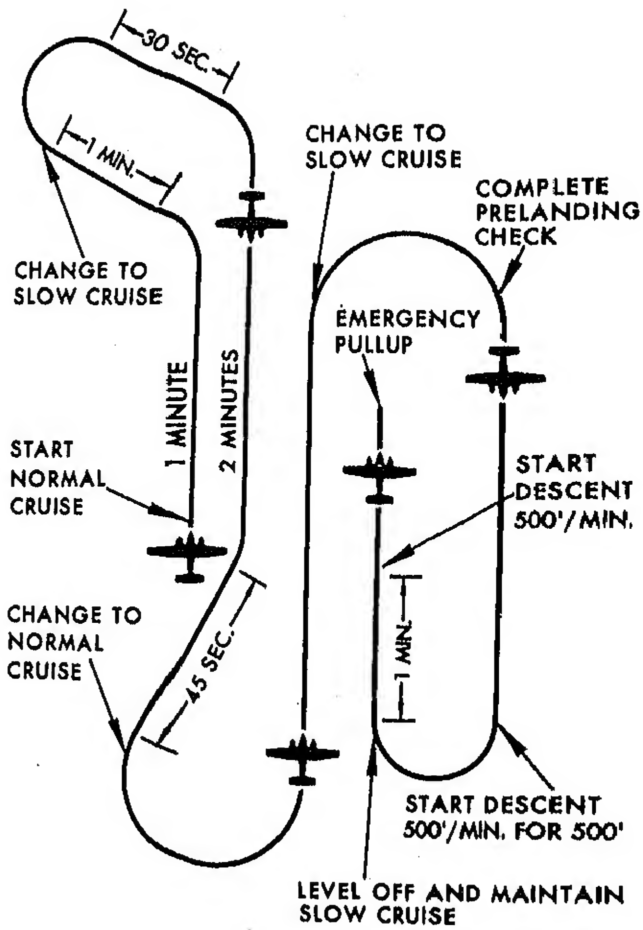

Figure 6-4. - Pattern B.

(5) The airspeed is maintained following the final turn, and a descent of 500 fpm is established, followed by an emergency pullup after descending 1,000 feet.

b. The timing is consecutive since the time for each leg starts when the time for the previous turn has elapsed, regardless of the bank attitude of the aircraft. Timing is simplified if the pattern is always started when the second hand of the clock indicates the 12-o'clock position. The pattern may be memorized; however, using a card will give practice that will be valuable in accomplishing advanced work. Planning should take place when flying straight-and-level on the legs. The pattern can be started on any heading, but initial practice should be done on cardinal headings.

c. Errors common in the pattern B maneuver include—

(1) Failure to control rate of turn.

(2) Failure to maintain heading and altitude.

(3) Attempting to use the compass as a bank instrument.

(4) Poor bank control during changes in airspeed.

APPENDIX

REFERENCES

AR 95-1	Army Aviation; General Provisions.
AR 95-8	Operating Procedures for U.S. Military Aircraft Over the High Seas.
AR 95-11	FAA Flight Service Interphone Communications System Procedures.
AR 95-15	Aerial Flights; Piloting Aircraft; Parachute Jumps.
AR 95-32	Annual Flight Requirements for Army Aviators.
AR 95-63	Army Aviation Instrument Program, Aviation, Written Examinations, and Aircraft Suitability.
AR 95-67	Detailed Instructions for Implementation of the Army Aviation Instrument Program and Conduct of Written Examinations.
AR 95-110	Identification and Security Control of Military Aircraft.
AR 320-5	Dictionary of United States Army Terms.
AR 320-50	Authorized Abbreviations and Brevity Codes.
DA Pam 108-1	Index of Army Motion Pictures, Film Strips, Slides, and Phono-Recordings.
DA Pam 310-Series	Military Publications Indexes (as applicable).
FM 21-5	Military Training.
FM 21-6	Techniques of Military Instruction.
TM 1-225	Navigation for Army Aviation.
TM 1-250	Principles of Fixed Wing Flight.
TM 1-260	Principles of Rotary Wing Flight.
TM 1-300	Meteorology for Army Aviation.
TM 11-5558	Gyro Magnetic Compass Set AN/ASN-13.
TM 11-6605-200-12	Operation and Organizational Maintenance: Aircraft Magnetic Compass Type J-2.
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AFM 51-13	Instrument Flying for Helicopter Aircraft.
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NAVAER 00-80T-60	All-Weather Flight Manual. (Reproduced by FAA.)
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Collins FD-105	Integrated Flight System, Copyright Collins Radio Company, Cedar Rapids, Iowa.

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